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THE PRINCIPLES OF ANIMAL HYGIENE
AND
PREVENTIVE VETERINARY MEDICINE

BY

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TO THE MEMORY OF

MY PARENTS

PREFACE

The growing interest in the hygiene of animals and in livestock sanitary problems on the part of veterinarians and of the producers of animals stimulated the writing of this book. The place of healthy, productive livestock in the social-economic scheme of human existence serves as its justification. It was written with the hope that it may prove to be useful to students in schools and colleges as well as to livestock sanitarians, and those engaged in animal husbandry. The book is a summarization, as well as an evaluation, of the evidence presented in literature in the light of the author's observations and analysis. A brief list of bibliographic references is appended to each chapter for the benefit of readers who desire to acquaint themselves with source material, more extensive bibliographies, and as evidence of the cosmopolitan character of the problems connected with animal health. The author gratefully acknowledges his deep obligation to his colleagues W. W. Burr, F. D. Keim, H. H. Marvin, and M. H. Swenk for valuable counsel in the projection of the chapters on Soil, Heredity, Radiant Energy, and Disinfestation, and to Rose Harrison for the care and preparation of the manuscript. To Mrs. F. H. King the author is indebted for permission to make use of data on soil and ventilation published by the late Professor King.

L. Van Es

Lincoln, Nebraska
Spring, 1932

Après avoir assaini les maisons et graduellement amenè les habitants à se mieux nourir, à se mieux vêtir je voulus que les animaux se ressentissent de ce commencement de civilisation. Des soins accordès aux béstiaux depend la beauté des races et des individus partant celle des produits: je prêchai donc l'assainissement des étables. Par la comparaison du profit que rend une bête bien logée bien pansée avec le maigre rapport d'un bétail mal soigné, je fis insensiblement changer le régime des béstiaux de la commune; pas une béte ne souffrit. . . . Les bergeries, les écuries, les vacheries, les laiteries, les granges, se rebâtirent sur le modèle de mes constructions. Et . . . qui sont vastes, bien aérées, par consequent salubres.

H. DE BALZAC.

Le médecin de campagne, 1832–33.

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CHAPTER I

INTRODUCTION

There is reason for the belief that problems associated with disease are eternal ones and that, as such, they will continue in spite of all human efforts. This, however, by no means signifies that the struggle against disease is a hopeless one, and least of all does it suggest that we should cease in our efforts to eliminate sickness and to bring succor to its victims. The statement merely indicates that a capacity for morbidity is an inherent biologic quality. It may even have its place in nature as a means by which the survival of a species may become enhanced, secured even.

It can be accepted as a fundamental truth that, on the whole, nature is but little concerned about individuals. Their physical well-being is frequently rather ruthlessly upset, and they may be destroyed in great numbers by the forces of nature. On the other hand, species are always jealously guarded and preserved within a wide range of biologic possibility.

If the members of a species increase to such numbers as to threaten or exhaust the supply of food upon which its continuation depends, nature may restore the disrupted bionomic equilibrium by the agency of deadly disease. In a similar manner, the normal relations between an animal population and the available food are kept in balance by what is commonly designated as the natural enemies of the species concerned.

When a species outbreeds its food supply it must eventually perish unless by some means the balance is restored and maintained. It is a matter of observation that disease may be one of these means.

Morbidity may be viewed from two angles: first, from a bionomic, and second, from a purely social, economic, or sentimental, view-

point. We are primarily concerned with the latter aspects, but in order to develop a logical understanding of the subject of disease, its place in the scheme of biologic existence must not be kept out of mind.

Because of the limitations of our range of observation, we have come to associate disease especially with man and his livestock. The opinion is even encountered that animals in the wild state are always healthy. This is by no means the case, and the error is largely based on the fact that, in our contacts with wild life, sick animals are not seen. We scarcely ever see even the ones that succumbed to old age. We do not, and cannot, subject them to clinical examination, and the only ones we observe are the strong, healthy ones, the others already having been eliminated.

For many reasons, man and his domestic animals are subject to a greater assortment of diseases and probably also show a higher morbidity rate, but to accept freedom of disease as a special attribute of wild life would be a mistake.

Wild animals also have their diseases and parasites which may impair or even destroy their health, but commonly these are not conspicuous enough to attract attention. Only when some highly fatal disorder exterminates large numbers may the fact become revealed that also among animals living in their natural habitats high rates of morbidity and mortality may prevail. There is evidence enough of such outbreaks, and, at least in some of them, it could be shown that they were a sequel to a disturbed ecologic state and tended to serve as its corrective.

In the causation of diseases of man and of the domesticated animals ecologic faults are also fundamental, for, so far as their genetic equipment is concerned, the domesticated animals have, to a large extent, retained many of the qualities of their ancestors and show similarity to their wild relatives as they exist today. They have, at least in part, remained more capable of adjusting themselves to an environment normal for the latter than to the one provided by their masters, although in many respects they would no longer be able to maintain themselves in the natural state.

Furthermore, they are apt to react to disturbances in their ecologic relations precisely as the ancestral stock would do under similar circumstances. Such reactions may express themselves by disturbances in health; disease, or by default or perversion of important functions. As examples of the latter, mention may be made of the failure to reproduce, common in many animals kept in captivity,

their agonizing nostalgia, their perversions, their psychoses, conditions as yet unfathomed by morphologic or biochemic pathology.

The genetic equipment of all living things provides for variation, and this power to vary, shown by all species, expresses itself in the plasticity that enables animals to adapt themselves to the changes of environmental conditions which, slow in their consummation as they may be, are, nevertheless, always in the course of progress. The time required to bring about new adaptations is, on the whole, attuned to that involved in the cosmic change which makes them necessary for the maintenance of specific existence and they may be entirely induced by it.

If changes in a previously well-balanced ecology proceed with greater rapidity than the power to vary can compensate for, normal adjustments may become so disturbed as to place the animals concerned in jeopardy. This is apt to happen in the progress of domestication, during which animals are subjected to environmental changes coming about with much more than cosmic speed.

Such changes in ecologic relations may ultimately lead to morbid conditions, in fact, are often indirectly responsible for many diseases. A close analysis of morbidity shows the great preponderance of extrinsic etiologic factors over intrinsic ones; there probably does not exist a natural phenomenon or force which, under given circumstances, may not play a part among the causes of disease.

Indeed, it does not require a cataclysmal alteration of environment to upset bionomic relations and to cause morbidity as a result. As long as a normal ecology prevails, grazing animals, the domesticated ones included, do not partake of the poisonous plants of their range; only when food becomes scarce will hunger force them to eat any forage available.

The same influence, but swifter in its operation, may be seen at work when sheep in close formation are driven across a "poison range." The animals in the van of the herd pick up all the wholesome, desirable food plants, so that the trailers have to take what is left and are thus forced by the mere impulse of hunger to consume a forage which destroys them. Such an apparently innocent change of environment as the erection of a wire fence across a natural prairie may furnish a contribution to morbidity. It tends to hold animals to a limited area, prevents them from following their instincts to search new grazing grounds in the face of scarcity, with the result that they must eat the poisonous vegetation of their range which was carefully avoided as long as the natural food supply lasted.

The concepts, health and disease, cannot be sharply defined. Both are subject to a complex of contributory factors, either associated with the animal organism itself or with the environment in which it must manage to exist. In the former, such factors as the intrinsic capacity for adjustment and adaptation, the state of organic perfection and efficiency—constitution—are of determining influence. The latter comprise the place of abode, the ambient medium, food and drink and, above all, the biologic forms with which the animals concerned are compelled to compete or which may have to be faced as natural enemies or as actual or potential parasites. Intrinsic, as well as extrinsic factors, thus, may not only exercise their individual influences, but may operate in combination, either for good or for evil, as the case may be.

It seems obvious that an undisturbed specific existence is largely dependent on a more or less perfect adjustment of intrinsic and extrinsic factors. As long as such an arrangement prevails, a state of health is apt to continue. On the other hand, if adjustment fails or is interrupted, the consequent disturbance of ecologic relations may give rise to the inauguration of pathologic processes: disease.

Although the capacity for morbidity can be regarded as an inherent one, it does not very conspicuously manifest itself in animal populations living in a natural state and occupying a long-accustomed environment. Under such conditions natural selection has, in the course of ages, brought about an approximately perfect balance, an adaptation to the available food supply, to climatic factors, to topographic qualities, to competing forms, and to other elements of ecologic import.

This type of bionomic balance may even include an apparent compromise between the animal organism and its parasites. Under such circumstances, so far as a given species is concerned, its ecologic relations are practically perfect, and the factor of disease, although never entirely absent, does not constitute a serious menace.

If, by some cause or other, the normal ecologic relations become disturbed, the way for disease may be cleared, and this status may endure until slowly moving nature has developed new adjustments by which it is always apt to protect specific existence.

No factor in the disturbance of normal ecologic relations has been more potent than man himself. In the course of the process of his own domestication, and that of his livestock, his acts have commonly, if not always, conflicted with the slowly evolved natural conditions and forces under which species can safeguard themselves against

extinction. Man, while progressing toward social life, while acquiring the very rudiments of his later civilization, no doubt has had to upset many of his own bionomic adjustments and as a result also had to pay a penalty for doing so in more than one instance. His gregariousness, budding into civic life, loaded him with parasites readily acquired from his house mates and neighbors. His concentration in large numbers, in narrowly confined spaces, exposed him to the hazards associated with malignant infections.

When he partially or wholly abandoned his open-air mode of living and began to inhabit sheltered enclosures, the terrific incubus of tuberculosis and pulmonary disease was fastened on him; even for the invention of window glass he had to pay a price in rickets and all its immediate and remote sequelae.

The domestication of animals, probably synchronous with the dawn of civilization, could not have been less disturbing to primeval bionomic adaptations. We may fancy what happened when the domestication of the horse had so far advanced that man could begin to shift some of his burdens to this larger and more powerful animal.

The horse, perfectly adapted to an existence by grazing and browsing, was equipped with a digestive apparatus capable of transforming this type of food into energy. Provided with a superb, perhaps perfect, locomotor apparatus, the animal could wander far and wide in search of food, and yet always had a speed reserve which permitted him to escape from his natural enemies.

This idyllic ecologic arrangement between a masterpiece of biologic mechanics and the environment in which it had to exist became deranged by the intervention by man. Its extremities, in the course of evolution, had dropped all its phalanges but one, and this was protected with a modified nail or hoof, so constructed as to fulfill all the requirements for life under natural conditions. It was, however, not designed and is not now designed, to withstand the increased wear and tear incidental to its new functions of a carrier of burdens or of a means of rapid and long-distance transportation. As a corrective, his master, reasoning and tool-using animal that he was, invented the horseshoe, or the contrivances that preceded it, and thus solved the problem, at least partially, by perhaps one of the earliest devices of hygienic import.

However, he did not solve all the problems arising from the horse's disturbed ecology under domestication. In order to meet the increased fuel demanded by the muscular apparatus, now largely used to move the burdens of man, a food more concentrated than that

which supported his wild ancestors had to be provided for the domesticated horse. For such a diet the equine digestive organs were not so well designed, and digestive disturbances became a more or less special attribute of the domesticated solipeds. Even the more hygienic feeding of a later day could not fully prevent the disorders collectively described as "colic" from remaining a prominent factor in equine morbidity and mortality.

No doubt, the structural and functional plasticity of the somatic complex may permit the establishment of new adjustments, but this is so tedious a process that the correction may come several generations too late for the requirements of man, and hence the latter must, in some manner, intervene in order to escape, or at least alleviate, the penalties by nature imposed.

If the tribulations of the earliest phases of domestication could again be witnessed, much that is fundamental to modern hygiene might be revealed. Something akin to the earliest domestication may yet be observed in zoological gardens, certain game preserves, and in connection with fur farming. The necessity of deranging ecologic balances makes fox farming, as yet, a more or less precarious business.

An outbreak of coccidiosis among muskrats belonging to a fur farmer, some years ago, may illustrate what may happen when ecologic relations become upset. Like many other species of wild animals, the muskrat, in the natural state, is the host of coccidia. It is not known how constant this host-parasite relation is, but there is reason to believe that under normal ecologic adjustment there has come about between host and parasite what may be termed a compromise which permits the host to prosper in health and allows the parasite to exist and to propagate in, for it, normal bionomic conditions.

In the natural state only a certain number of muskrats can occupy a given area, and safety against hyperparasitization may be assured by the wide scattering of the oocysts and hence the reduction of the number that can readily be taken in by the occupants of the range. In this manner it becomes difficult for the potential young hosts to acquire more coccidia than is safe for them at an age when susceptibility, or rather vulnerability, is at its maximum.

When the fur farmer, quasi-domesticator, removed the rats from their natural habitat, in spite of his efforts he seriously upset the natural arrangements by which host and parasite species can peacefully coexist. He placed his rodents in confinement in a circumscribed area, made "sanitary" by concrete construction. He provided basins made of the same material, filled with water, to imitate in part a

natural muskrat environment, and in an attempt to still more enlarge this supposed advantage, he procured for his stock the natural food from a nearby swamp and distributed this over the shallow basins. In spite of all this care, disaster was not long delayed.

At the same time that the pangs of domestication were being mitigated, the element of dilution of the oocysts eliminated by the older rats was effectively canceled, and simultaneously a rat population, denser than under natural conditions would be ecologically permissible, occupied a very circumscribed, fixed area. Thus, concentration of parasites and hosts, operating in a vicious circle, polluted the small volume of drinking water to such a degree that the young animals, within a very short space of time and at the very height of vulnerability to coccidial invasion, were compelled to take in thousands of oocysts instead of the few available in a natural environment. Such an assault could not be withstood, and the rats succumbed, to the chagrin of the farmer, and also as a catastrophe to the parasites, the ecologic adjustments of which were as badly deranged as those of their hosts.

Not all the disturbing effects of domestication are confined to environmental conditions or bionomic abnormalities. It attacks the very bioplasm of the animals concerned. By taking advantage of the inherent capacity for variation, man, by selective breeding, changed over the original pattern of the animals he found at the dawn of domestication. With ample justification he did so for his own profit, often did it wisely, but not without profoundly changing the relations of his stock and their disorders.

One example, that of the dairy cow, may be cited in illustration. Early man found the bovine female provided with a mammary apparatus designed to supply sustenance for the offspring only prior to its capacity for independent existence. The udder was small, well kept out of harm's way in the vault between the thighs. The secretion of milk, just enough to nourish her young, was moderate and constituted no drain on the body's reserve of substances essential to its normal metabolism.

After it became evident that milk is also a perfect food for man, the practice of selective breeding gradually changed the bovine mammary equipment so that its yield became many times that of the original ancestral stock. It grew beyond its original protecting confines, became more exposed to external violence, and simultaneously lost much of its pristine resistance to infection. In fact, the udder of the improved dairy breeds of today has become a veritable noli-

me-tangere, and special care, largely hygienic, has become necessary to preserve the organ and its functions. Moreover, the tremendous secretory activity of the organ during the parturient period may actually deplete the calcium reserves of the body and become the cause of the morbid state now designated as parturient paresis.

The incidence of the transmissible diseases also is materially influenced by domestication. That animals in the state of nature are susceptible to microbic infections common among domesticated ones has been shown frequently enough. That such diseases may spontaneously assert themselves among wild animals is a matter of observation, and that the etiologic factors of communicable disease existed as parasites of wild animals and probably continued to do so after they became domesticated must be admitted on biologic grounds.

In comparison with conditions prevailing in a state of domestication, such diseases under more natural conditions tend to spread more slowly and show a lower incidence as long as ecologic balances are being maintained. As a rule, such disorders are apt to become disastrous only when bionomic relations become upset by such factors as over-population, failure of the food supply, the concentration of large numbers about water holes in times of drouth, and the introduction of new biologic forms of pathogenic antecedents.

Although in the scheme of nature the factor of disease may be useful in the correction of unbalanced ecologic relations, morbidity may become a menace to specific existence when accompanied by a maximum mortality. Danger to an animal population arising from such a contingency is normally averted by new adjustments. In these, fecundity and the gradual development in the animal organism of a specific resistance to the biologic factors of disease, often reciprocally complementary, are determining factors.

Under their operation, even the most virulent of diseases may, in time, be compromised with by ecologic adjustments of host-parasite relations. Syphilis among Caucasians is no longer the malignant scourge of an earlier day. Smallpox and scarlet-fever are not so formidable as they were a century ago. The tuberculosis morbidity in the white populations of Europe has gradually declined for not less than seventy-five years and did so independently of sanitary efforts, however potent these are.

Animal diseases enzootically established are, as a rule, less virulent to the animals which long inhabited the regions involved than to those introduced from exempt territory. This phenomenon may

be a factor fundamental in the periodicity of certain diseases, in the rhythm of morbidity. A resistance to a given infection develops, due partly to natural selection, partly to sublethal exposures to the virus, and morbidity dwindles. A new population grows up, not exposed and hence without incentive to preserve its resistance, and with a new introduction of the virus the morbidity again rises.

The complexities of the phenomena associated with morbidity are by no means lessened by the power to vary, which, being inherent to all biologic forms, also gives plasticity to the character of disease producing parasites, macroscopic as well as microscopic. As a result, new capacities, new affinities may arise, if needed in the preservation of the species. A microbic form, existing even as an obligate parasite, as long as it remains capable of adjusting itself to altered conditions, is well ensconced in nature. Apparently its specific existence is as secure as that of the higher forms of life, if not more so.

Typhus fever, notorious as the deadly jail fever of earlier times, had practically disappeared from civilized peoples, until a war which turned their existence topsy-turvy came along. It disrupted the existent ecologic relations of mankind, and again the malady slaughtered its thousands as in the days of old.

On the other hand, an established morbidity may be mitigated or removed as a result of changes of a bionomic character. Thus, the trypanosomosis ngana, transmitted by the tsetse of Africa, in certain regions, made animal husbandry a precarious undertaking. The large game animals inhabiting the territories concerned served not only as an inexhaustible infection reservoir, but also as the natural sources of food for the flies.

At a given time, cattle plague, a disease exotic for this region, became introduced, destroyed the game animals, and in a measure eliminated the trypanosomes as well as the vector flies. The introduction of an extraneous biologic element, in this case the virus of cattle plague, materially changed a well-established morbidity complex.

Of no less interest is the disappearance of malaria from certain populations. In this case also there may be warrant for the belief that changes in ecologic relations were, at least in part, responsible for the phenomenon. It is well known that large areas now practically free from malaria were formerly badly infested. The malady frequently proved to be a formidable plague among pioneer populations, but in course of time it disappeared completely and spontaneously.

The precise manner by which this came about may never be revealed. Malaria mosquitoes are still present in some of the areas concerned, but without doubt, they no longer propagate and transmit the etiologic factor of the disease. The latter has disappeared. In its life history it depends both on man and on the mosquito not only to serve it as host, but also, in the case of the insect, as a means of contact with the mammalian host. It is an obligate parasite of the latter and cannot develop in other mammals. If the vectors were to turn to other animals in order to feed on their blood, the life cycle of the malaria parasite would be disrupted. Certain observations tend to show that in some areas, at least, this actually happened, and that the introduction of appreciable numbers of domestic animals supplied the mosquitoes with a new source of blood so that man, less available, as such, was no longer inoculated, and the mosquitoes, now feeding on animal blood, failed to become infected with the malaria protozoon. It is possible that the introduction of a new biologic element had changed the ecologic balance previously maintained between parasite, vector, and host.

On the whole, diseases among domesticated animals are more common and more numerous than they are among animals living in their natural state. Some diseases are peculiar only to the domesticated species, and such disorders as tuberculosis, abortion disease, colibacillosis, paratyphus, and streptococcus infections are either extremely rare among wild species or absent altogether.

Primarily responsible for the greater morbidity rate prevailing in domesticated livestock is the absence of a balanced ecology for which the animals are yet more or less specifically prepared. Their housing, justifiable as it may be from an economic standpoint, forms no part of their natural bionomic requirements. As in man, it promotes tuberculosis and pulmonary diseases and causes the young to acquire rickets, which, in turn, predisposes them to certain infections seen only under the conditions imposed by domestication.

Concentrated in relatively small spaces or areas, they are unduly exposed to contact infection. The direct and indirect contact with fecal matter supplies a hazard which is not present in the wild state and which in certain domesticated species is responsible for most of the disorders that afflict them. Their food is necessarily more designed for profitable returns than for its physiologic fitness, and their whole mode of living is prescribed without regard to their inherent adaptability.

In the progress of domestication and in its pursuit of economic

ends, man had continually to contend with the eternal forces of nature, which cannot be overcome and which he cannot always set aside. He found himself in conflict with nature, found himself engaged in a pursuit to a degree incompatible with the designs of nature. The latter are concerned only with the preservation of the species, whereas man, in his own struggle for existence, must concentrate his energies on the preservation and well-being of individuals.

From early times on, the grower of domesticated livestock which is largely removed from the harsh but yet protecting care of nature, has been confronted with the problem of disease arising commonly from a faulty environment, from the introduction of macro- and microparasites and from the alteration of the primeval pattern of his animals. He has been compelled to devise ways, means, and measures to compensate his animals for whatever domestication deprived them of in natural protection against the influences making for morbidity.

These means, ways, and measures we now recognize as hygiene and preventive medicine. In the orderly development of domestication and animal husbandry they must begin to function whenever natural ecologic adaptations have become disrupted. Hygienic measures only can protect individuals that must exist under conditions to which they may be imperfectly, or perhaps not at all, adjusted.

No doubt, a sort of empiric hygiene has been practiced, wittingly or unwittingly, since the dawn of civilization, but its direct influence on morbidity was probably left out of consideration until a much later day. Disease was still something supernatural, something detached from earthly influences; it could be affected only by charms and incantations.

When faith in the latter began to fade, means of cure by drugs and surgical procedures came to be accepted, and they continue to be applied to this day. In a measure, they justified their adoption when disease had to be faced as an accomplished fact. The art that heals, that succors, that restores health to whatever may suffer, remains the objective of medical and veterinary efforts. For ages the curative function of medicine was the only one and it will, for all time, continue as one of its major tasks.

To this task the modern era has added another, equally important, perhaps even more so—the prevention of disease. Efforts with that objective in view are probably as old as humanity itself, but it was not until relatively recent times that it became possible to base them on more exact knowledge and to apply them in a rational man-

ner. They belong, therefore, to the era of modern medicine, the advent of which came with the introduction of certain optical improvements of the compound microscope and began by challenging old and cherished beliefs.

The modern era witnessed the development of the experimental method of inquiry, which, in the hands of the great masters of the nineteenth century, revealed disease as a purely biologic phenomenon, not removed beyond the understanding of man. Their labors supplied the bases for a rational preventive medicine and hygiene.

Before long the worth of the newly acquired principles and viewpoints became recognized, and the general emphasis of medical and veterinary interests began to shift from attempts to cure to efforts to prevent.

The achievements in disease prevention of the last half century have more than justified its recognition as a potent factor in the preservation of health. In no field of medical endeavor is the wisdom of the shift of the emphasis from curative to preventive efforts more apparent than in veterinary medicine, which is concerned with disease chiefly because of its economic significance, and in the function of which sentimental considerations are, on the whole, of subsidiary importance.

The fact that most disorders belonging to this group are not in the least amenable to curative treatment and that their successful prevention lies well within the range of possibility is warrant that hygienic methods will be and must be increasingly stressed in the solution of problems associated with morbidity.

The maintenance of health and the prevention of disease, the objectives of what we designate as hygiene, more than ever before will become the principal task of the veterinarian. Especially those more particularly concerned with the food-producing animals must think in terms of hygiene, for their success is in no small measure dependent upon their knowledge of the subject, its place in domestication, its underlying principles and technique of their application.

The task of animal hygiene is to create conditions under which livestock can exist as individuals, to eliminate factors which in the scheme of nature are incompatible with physical well-being, to compensate for the deviation from natural ecologic relations incidental to domestication, to exclude the biologic causes of transmissible disease, and to do all this at a cost not out of proportion to the actual advantages to be gained.

In order that hygienic efforts may yield fruit, their importance

must be inculcated in those engaged in the pursuit of animal husbandry. As a general rule, the preventive instinct is not yet strongly developed. The faith in "cures" and the practice of dealing with disease problems only after they have arisen, which thousands of years of magic and dosing have firmly established as a more or less integral part of human nature, is antagonistic to disease prevention. It can be overcome only by sound precept; it should not be exploited. The owner and breeder of livestock must be made aware of the value of anticipatory hygienic measures before they can be made generally useful.

In its scope hygiene includes three distinct divisions:

(1) *Genetic hygiene,* which gives consideration to the genetic equipment with which animals have to face the vicissitudes of specific existence and the hereditary influences which may affect their usefulness to man or play a part in the transmission of certain morbid conditions.

(2) *Environmental hygiene,* which pertains to the various factors associated with or present in the surroundings in which animals must exist. It is concerned with the reaction of animals to changes in the ambient medium peculiar to the state of domestication, with the quality of water, food, soil, habitations, etc., including the means available to make or keep an environment salubrious.

(3) *Biologic hygiene,* the division in which consideration is given to relations of animals with the biologic forms which, as gross or micro-parasites, may affect their health, and to the available means by which the diseases caused by them may be prevented. It constitutes that part of medicine known as preventive medicine.

A strict separation of the three divisions which compose hygiene as a whole is not possible. The very fact that the need of hygienic efforts arises from the interrelations between animals per se and the many factors that constitute environment precludes a narrow demarcation of the three fields. The division merely serves as an expedient to logical presentation.

Hygiene, as a science and as an art, rests on foundations as complex as the very factors which enter into the many aspects of morbidity. Its roots go deeply into all that concerns life and living things. General biology, including physiology, genetics, ecology, bacteriology, parasitology, entomology, immunology, and pathology, defines its principles. Physics, chemistry, engineering, meteriology, climatology, the earth sciences, contribute to its fundamentals and

to a large extent make its usefulness possible. Clinical medicine is its handmaiden, and vice versa, one complementing the other.

Hygiene may be compared to a bridge between old and new bionomic relations; in the light of Lenz's concept of disease as life at the limits of the capacity for adaptation, it is on this very boundary where its field of action lies. In the same region domestication has its place, and there also animal industry must operate.

It is the task of animal hygiene to remove or to reduce the hazards associated with life in more or less artificial environments, to enhance animal well-being, to forestall morbidity in a manner compatible with the economic purposes of husbandry.

The science and art of hygiene must face many perplexing problems; in its approach to their solution it may be groping, hence disagreements among its preceptors and practitioners must be expected. The latter merely show that hygiene supplies no exception among the other sciences concerned with life and is neither complete nor static. It is mobile, and progressive, its last chapter will probably never be written, and earlier ones will always remain subject to revision. Notwithstanding these facts, its foundations are sound and secure. In a large measure hygiene has become indispensable to the progress of civilization.

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CHAPTER II

HEREDITY

THE genetically acquired physical and functional equipment with which animals face the hazard of existence cannot fail to be a subject of importance to the livestock sanitarian as well as to those engaged in animal production. Its importance is further emphasized by the fact that for many centuries the genetic transmission of defects was unhesitatingly accepted as a primary etiologic factor, a belief which commonly found expression in legislative attempts to improve the qualities of livestock by the rejection of breeding stock affected with abnormalities reputed to be hereditary.

Many of these beliefs are no longer tenable in the light of present-day evidence, and others are seriously challenged in regard to the firmness of their foundation. Owing to the changed views on the subject of heredity induced by the development of the science of genetics since the beginning of the present century, there seems to be warrant to review briefly whatever evidence has been brought to light on the subject in order to ascertain, if possible, to what extent the genetic bases of morbid or semi-morbid conditions must be given consideration in a general scheme of the hygiene of livestock.

Genetic Considerations.—The animal body has been conceived (Weismann) as consisting of two distinct structural units, the germplasm and the somatoplasm. The former is supplied by the germ cells (gametes) eternally renewing themselves in succeeding generations, and the latter furnishes the mechanical and functional equipment necessary for individual existence.

The germplasm, by the union of the gametes in sexual reproduction, not only sets aside the cellular elements by which a succeeding generation may propagate itself, but from it the primary structures are split off which give rise to the somatoplasm, the body equipment of a new animal. Thus in this process of cell division and differentiation cells are especially set aside to serve as germ cells for the future individual.

The germplasm may be regarded as the immortal part, as the carrier of that which assures the continuation of a species, whereas

the somatoplasm, the mere individual organism, is mortal and doomed to decline and disappear.

With all its immortality the germplasm is but a slender thread which connects one generation with the succeeding one. Yet, the germ cell, microscopic bits of substance, contains such a mass of factors and potentialities as to make it the most wonderful and intricate of all biologic structures. The gametes, united in the course of sexual reproduction, contain not only that which determines whether they shall develop into a horse, man, ostrich, or fish, but also the factors which will endow the resulting somatoplasm with a distinct individuality.

The fertilized egg cell or zygote thus encloses all the factors which may operate in the establishment of all the characters which a new individual inherits from its parents. It is the vehicle of true heredity, which must be regarded as separate and distinct from any other means by which a parent may confer a given quality upon its offspring and, above all, any character of pathologic import.

Thus, in any discussion having to do with inherited qualities, such subjects as intra-uterine injuries or infections, acquired characters, telegony, maternal impressions, etc., must be excluded. Such phenomena have no genetic importance, and so far as they may be actual, they lie outside the scope of heredity. Only that which is intrinsic to the zygote can be of any genetic consequence and worthy of consideration from an aspect of genetic hygiene.

The narrow bridge which genetically connects one generation with the succeeding one consists of the reproductive cells; they alone contain the factors which are essential in the acquisition of parental or ancestral characters, be they specific or individual.

The offspring thus generated conforms in a general way very closely to the pattern, morphologic as well as functional, of the species to which it belongs. It is also apt to resemble the parent stock very closely with regard to individual characteristics, although this resemblance is never a perfect one. Differences are always to be noted, and these determine a distinct individuality, for this individual never appeared before and will never be seen again.

These differences, conspicuous or slight, are designated as variations. They may be regarded as evidence of the plasticity of the soma by which animal species are capable of maintaining themselves in nature through adaptation to changes in the environment in which biologic forms must manage to exist and to which they have been, and will be, eternally subjected. The inherent potential variability

is the foundation upon which varieties, strains, or new species have been built in the course of evolution.

The primary capacity to vary is intrinsic to the germplasm, but the influence of environmental factors is also potent in determining specific, as well as individual, characters. The genetic equipment of a biologic form constitutes what is known as the genotype; the influence to which the latter may be subjected by environmental factors from the moment of zygote formation determines the actual form or phenotype. Thus, the properties of an animal are the result of, first, that which constitutes inherited developmental or hereditary factors, and second, the non-inherited, environmental influences.

Variations are the result of recombination of hereditary factors and of the influence of the environment. In addition to this mode of varying there occur entirely new or unexpected modifications. These are known as mutations, and they constitute heritable characters apparently not at all peculiar to the parental stock and not depending upon segregation and recombination. Their cause is not known but apparently, at least, must be found in influences which suddenly act upon the genotype.

Between successive generations a genetic relation exists which is expressed by the reappearance of parental or ancestral qualities conveyed by the intrinsic factors present in the germplasm.

This constitutes heredity, and to the geneticist this merely means the presence of identical hereditary factors. The nature of these factors is not known, but it is apparent, if not certain, that they are associated with the chromosomes of the germ cells. They are spoken of as "genes." It is not impossible that they are chemical substances capable of increase without change of characters. In their action they may be compared to enzymes.

Whatever the nature or composition of a gene may be, it acts as a determinant of a given character of the new individual. Thus, the essential of heredity is the transmission of the genes, which govern characters from generation to generation. Heredity is no more than this. The characters of animals per se are not themselves transmitted; they come about in the developing individual only under the influence of these genes in the somatic cells and by the manner in which the individual soma reacts to its environment.

The genes for the various characters are potent determinants and must be present in the zygote, but the adult characters themselves can come about only in the further progress of development in which environmental conditions also exert their influence.

The union of the gametes constitutes the zygote (fertilized ovum); each of the two contributes an equal share to the stock of its chromosomes. In the further division of the zygote the new cells thus formed contain as many chromosomes derived from the sire as from the dam. Thus every heritable character of a living being is determined by a paternal and a maternal contribution.

If each of the two parents has supplied a perfectly equal genetic share, or, stated in another way, if both participating gametes are of identical genotype, there results a zygote which receives twice the same genotypic constitutions. Such a zygote is of double homology and is called homozygote. The resulting individual is also so designated. Homozygoty thus comes about if each gamete contributes to the resulting zygote the determining gene for a given character.

A homozygote normally yields only genotypically equal gametes, so that, in so-called pure line breeding, stability and fixity of a given character can be expected, because homozygotes always remain homozygous in the event of mutual fertilization.

If, on the other hand, gametes of unequal genotypic character are united, the zygote is unequally double; a heterozygote for the character involved comes about, and its genotypic constitution is dissimilar or heterozygote. Every cross between two non-identical genotypic germ cells results in heterozygotes.

Thus, any zygote in which the two genes for a particular kind of character are alike is called homozygote, and a zygote in which these genes of a given pair are unlike is designated as a heterozygote.

An individual characteristic that is passed on from parent to offspring through succeeding generations is known as a unit character. When parents with complementary unit characters are mated, it is found that one character may predominate over the other. This phenomenon is designated as dominance. The character which prevails is dominant, and the one which does not prevail is recessive.

The unit characters determined by their genes, as a rule, do not blend but remain separate and distinct, a phenomenon spoken of as segregation.

Each individual is made up of a complex pattern of inherited characters, some of which are dominant and others recessive. Dominance depends on a higher valency of the hereditary factor or gene for a given character and this masks the influence of the factor of lower valency, the recessive one. Although the dominant hereditary factor suppresses the recessive one, it does not destroy it.

Some unit characters which may be of pathologic portent are

transmitted by sex only. Such a character is said to be sex-linked. Examples of this are seen in hemophilia, color-blindness, night blindness, and some other morbid or semi-morbid conditions.

It was shown by Mendel that, if two individuals possessing different characters are mated, the offspring of the first generation will as a conspicuous mark carry the character which in one of the parents as compared with the other is the dominant one. In the second generation, however, one-fourth of the progeny will also show the character of the weaker of the parents, whereas another one-fourth will carry the so-called dominant character and one-half a mixture of both characters.

In the third generation the one-fourth which possesses the so-called recessive characters unmixed, obtains this character and transmits it to the offspring, whereas of the other three-fourths, one-third are pure dominants which transmit their character to their progeny. The remaining two-thirds beget an offspring of which one-fourth possess the dominant character, pure or mixed, and one-fourth the recessive one unmixed.

The observations and shrewd conclusions of Mendel proved to be fundamental and are now recognized as among the great contributions to biology. They are embodied in Mendel's law: a plant or animal impure for a given gene yields as many germ halves with as without this gene.

Etiologic Aspects.—For ages, heredity was confidently regarded as a very important factor in etiology. During the entire era which preceded the advent of modern pathology, bacteriology, and biochemistry, it was the most readily available explanation of the underlying causes of disease. There was a certain finality to the belief in genetic transmission; it explained things in a simple and satisfying manner, and there was no way to subject the problem of disease to a more critical analysis.

As late as the seventeenth century a veterinary writer enumerated not less than forty hereditary diseases in the horse alone. Since that time this number has been continually and substantially reduced as effective methods of inquiry were developed and as heredity, as a physiologic function, came to be better understood.

Although the old beliefs with regard to the hereditary foundation of animal defects and diseases still enjoy a measure of popular approval, it is now generally recognized that the long list of morbid conditions once reputed to be genetically acquired can no longer be maintained.

On the other hand, it must be admitted that the knowledge pertaining to the subject is extremely incomplete. In the absence of carefully kept genetic records extending over long periods it is commonly difficult to determine to what extent heredity was a determining factor in the development of congenital defects and to what extent they were induced by purely external influences.

The frequent occurrence of a given defect in several generations of the same family is not necessarily a justification for designating it as heritable. Such defects may come about without a special inherent factor being responsible. They may result from external conditions peculiar to an environment to which several generations are particularly exposed.

In the light of the present-day conception of genetics, the characters of any biologic form are never hereditarily transmitted as such. What is transmitted are hereditary factors or genes, which, in the presence of environmental influences, may be determinants for certain characters of a new individual. This applies to normal characters as well as to those which may be classified as pathological. Diseases or defects, thus, are not genetically transmitted. Genes may be passed to a new generation which eventually may render a defect possible, but this does not constitute disease. The thing transmitted is merely a genotypic potentiality.

Fundamentally, there are no true hereditary diseases, but a predisposition for a pathologic state may be transmitted from generation to generation, and this predisposition may be intrinsic to the genetic substance or genes. There may be a fault of constitution of the genes, a derangement of the genotype, which, under the influence of environmental factors may permit the development of a defective, abnormal phenotype. Thus, a genetically transmitted inferiority of body-building materials or faulty body constitution may, under stress of wear and tear incidental to existence, give rise to a pathological condition.

For the purpose of illustration it may be permissible to draw from a field not now included in that usually covered by genetics. A susceptibility to a given transmissible disease is not uncommonly inherent to only one animal species. The specific biochemic constitution of swine which, hypothetically at least, provides an affinity for factors associated with the virus of hog cholera, which, if satisfied, brings about a cataclysmic derangement of physiologic functions, is part and parcel of the genotype. It constitutes a liability of the species concerned, a wholesale *locus minoris resistentiae* await-

ing only the introduction of an environmental noxa, the virus, to precipitate a condition lethal to the phenotype.

Because of the fact that such an affinity or susceptibility is peculiar to an entire species, it is looked upon as a normal quality, but the interaction of the factors named serves to illustrate the difference between a genotypic potentiality, regularly transmitted from generation to generation, and the purely phenotypic phenomenon, viz., disease.

Hereditary disease, as ordinarily defined, has as its underlying causes: first, an unfavorable genetic equipment, and second, the influence of environmental factors. The former may be regarded as a predisposing and the latter as an exciting cause.

The hereditary factors which provide the possibility of defects may either be sublethal, merely handicapping an animal in the struggle for existence, or lethal, being self-limited because, before they can be further transmitted, they render existence impossible.

So far as hereditary factors may have a hygienic bearing, they pertain to the inheritance of morphologic departures from the norm, of functional derangement, of predisposition to particular morbid states (diatheses) or to variations in susceptibility to the specific transmissible diseases.

In the domestic animals, diseases or defects having a genetic base are relatively rare. Owing to their impairing the economic value of the various classes of livestock, the animal breeder has ever been concerned to eliminate the bearer of such abnormalities from his operations.

Unless some marked deviation from the normal pattern can be economically exploited, the interests of the producer are compelling in the selection of apparently sound breeding stock and of animals with constitutions fully adapted to the purposes of husbandry. A few defectives arising in a stock of animals with hereditary taint do occur, but their importance is relatively slight because of the elimination process more or less constantly in progress.

In the domesticated animals the propagation of variations in body qualities is not so rigidly suppressed, as they are under the operation of natural selection to which animals living in the wild state are subjected. If, on the other hand, the variations tend to be conducive to improfitable morbid conditions, they are not usually permitted to vitiate many generations. This, more than any other factor, is accountable for the paucity of the knowledge of hereditary defects among livestock.

The species of animals living in the natural state are commonly characterized by a marked adherence to the specific pattern by a genotypic purity or homozygoty. Aberrant forms have but little chance to impress their special characters on the species as a whole. The great mass of individuals determine the type, and this is perfectly adapted to a given environment. Variants are apt to be at such a disadvantage that their peculiar characters doom them to early extinction.

As a contrast, the human species, under the conditions imposed by civilization, neither is guided by the master mind which controls its matings, nor is it penalized by an inexorable nature, as in the wild animals, whenever unsuitable characters arise. The individual judgment of man, even at its best not always wise or well founded, is dominated by his sentiments, emotions, and conventions. As a result, the species has become extremely heterozygous to an infinite number of characters and has become burdened with a marked assortment of heritable abnormalities. In this manner has the civilized human race furnished the natural base for most of the knowledge pertaining to these abnormalities, and it continues to exhibit the most interesting and best-known examples of genetically acquired defects.

Hereditary Diseases.—Even though it may be inconceivable that certain diseases, as such, are solely attributed to a true genetic factor, the hereditary character of predisposition to a given defect must be recognized. The same may be true of certain malformations. Joest calls them "anomalia heriditaria" and regards them as being associated with inherent faults of the germ cells. These must be distinguished from the type of malformations, distortions, and deviations from the specific body pattern which came about through extrinsic influences during intra-uterine life and which are not genetically transmitted.

The defects and malformations commonly recognized as heritable include a genetic form of sterility of mares, so-called "bull-dog" calves, polydactylism, syndactylism, congenital cataracts, epithelial defects in calves, cryptorchidism, deafness, cleft palate, microphthalmia, coloboma, glaucoma, brachygnatia superior et inferior, entropion and ectropion, as well as certain hernias.

It is probable that in many of the defects named a genetic transmission plays a part. The dominance of syndactylism as seen in swine cannot be doubted, and the congenital epithelial defects of calves described by Hadley are by him ascribed to recessive factors.

Certain hernias studied by Warwick could also be attributed to recessive factors. In many of the others the mode and character of heredity have not always been established on solid genetic evidence, and knowledge about them rests largely on empirical observations. Some of these defects are lethal and tend to eliminate themselves from a breeding stock; others are semi-lethal or constitute such an impairment of the economic value of the animals concerned that careful breeders are bound to take them into consideration when reproducers are to be selected.

In a considerable series of defects which were once regarded as heritable the evidence of genetic transmission is unsatisfactory or obscure. In a number of these, there can be shown a distinct, inherent fault of body conformation resulting in an inability to withstand the wear and tear incidental to imposed functions which eventually may be expressed by pathologic changes. However, it is equally possible that even a number of defects which, by legislative enactments, now disqualify a sire for public service are entirely due to environmental causes. In the presence of a hereditary base for a faulty constitution, certain defects are merely a badge of genotypic inferiority.

It is especially in the horse, a species particularly exposed to stresses and strains of its mechanical equipment, that one encounters morbid conditions as a result of a faulty conformation. These may be genetically transmitted, but a careful analysis of the available evidence will frequently warrant the conclusion that extrinsic factors and a constitution poorly adapted to the task to be performed overshadow hereditary factors in their etiologic importance. A predisposing influence cannot always be denied to genetic faults, but this does not commonly act as an immediate cause.

This is especially true of the pathologic conditions associated with the locomotor apparatus of the horse, and hence they are rarely overlooked in stallions' registration laws based on the opinions which prevailed before the evidence could be challenged by the more exact methods of the geneticist.

Such defects as ringbone, splints, spavin, and curb commonly are due to environmental factors, but as already stated a hereditary faulty conformation or defective building material may play a part. A hereditary influence in the tendency toward the formation of exostoses is recognized by certain authors whereas others maintain that it is not possible to eliminate this defect merely by the selection of breeding stock.

Although there may be no sound base for the belief that ringbone

is a hereditary defect, there is agreement that a faulty conformation and position of the legs and phalanges inherent to certain animals should cause breeders to exclude individuals affected with ringbone from their breeding operations and certainly to do so if the unsoundness develops in young horses during their first working periods.

Large splints in young horses are to be regarded with suspicion because it is quite probable that this abnormality is associated with a faulty construction of the carpal region and an inferior quality of bone as family traits.

The pathologic complex known as spavin is probably no more than an expression of a mechanical and structural inferiority of the hock. It has thus far not been possible to demonstrate definitely a hereditary influence in the etiology of this form of joint disease. As evidence of a faulty construction of the hock, the frequent appearance of spavin in a given family should, however, not be overlooked by breeders.

The same consideration should be given to "curb." It is a mark which points out to the breeder that the quality of the hock as a mechanical device in locomotion should be carefully challenged. Weak, faulty hocks with unduly high calces are prone to develop this defect if the parts are exposed to stresses and strains which, in better-built animals, would cause no injury. Welch rightly states that, if registration laws do not contemplate the elimination of stallions possessing a "curby" or faulty conformation of hock regardless of the actual presence of the defect, no progress would be made in its prevention.

Such defects or blemishes as bog spavin, thorough-pin, and wind galls are subject to similar factors. They are most frequently caused by external influences, but it cannot be denied that these influences are most apt to assert themselves when a predisposing conformation invites difficulty, and such a conformation or quality may be genotypic in character.

In the case of side bones, the hereditary transmission of the unsoundness appears to be established on more solid ground. However, consideration must be given to the fact that the ossification of the lateral cartilages may also come about through external influences only, and then there would be no justification for the assumption of a hereditary factor and for the rejection of the animal concerned. However, in many cases it would be exceedingly difficult to differentiate between a congenital and acquired side bone.

The question whether or not hemiplegia laryngis of the horse

can be attributed to a heritable predisposition is still the subject of debate in which much contradictory evidence has been submitted. Although some authors reject the genetic transmission of the disease, the preponderating volume of opinions held by veterinarians and horse breeders is that heredity is a potent factor in the etiology of the disease.

Kronacher states that there are families in which "roaring" is so common that it is difficult to deny the part played by genetic factors. He cites Meershoek, who believes in a recessive hereditary factor and who states that a roarer stallion mated with a non-roaring homozygous mare begets sound colts exclusively, but that if he is mated with a non-roaring, heterozygous mare half of the offspring will be affected, and that sound but heterozygous horses may have roarers among their progeny.

Suckow goes so far as to state that hemiplegia laryngis in inheritance follows Mendelian rules and that 50 per cent of the offspring of roarers are born with the defect and that the other 50 per cent are not, without its being sex-linked. He also calls attention to opinions held by some that the predisposition to hemiplegia laryngis even is a dominant one and that if both parents are affected (homozygous) all the progeny are, or will become, roarers. If the mares are heterozygote and are mated with a homozygotous roarer stallion, they produce 50 per cent pure and 50 per cent impure roarers. Mated with sound mares such stallions beget a progeny that is 100 per cent heterozygous for the defect. A homozygous roarer mare produces 50 per cent homozygous and 50 per cent heterozygous colts, if mated with a heterozygous roarer stallion.

If such a stallion is mated with heterozygous mares he begets 75 per cent homozygous and 25 per cent heterozygous roarers, and if mated with a sound mare 50 per cent of the colts are heterozygous roarers and 50 per cent are sound.

It is quite evident that a large volume of genealogical evidence must be subjected to analysis before the nature of the genetic transmission of the disease will be clearly understood. However, even if prevailing opinions may frequently be found to be contradictory, breeders will do well to proceed with caution in the selection of their reproducers. They would certainly be justified in excluding animals in which hemiplegia laryngis appears before they have reached the adult stages of life or if the disease makes its appearance shortly after they were first put to work and in the absence of the influence of such disorders as strangles, infectious pneumonia, etc.

Dieckerhoff concurs in this opinion, and states that if the disease develops at a later period the animals concerned may be used without restriction.

Periodic ophthalmia has, for centuries, been regarded as a hereditary disease. Nevertheless it is more than probable that the etiology of this malady depends entirely on external causes, and no evidence available at this time clearly points to a hereditary predisposition. There is a general agreement that periodic ophthalmia has no genetic foundation.

Chronic hydrocephalus has been associated with a long narrow head and undeveloped cranial cavity, a so-called "flabby" constitution, and it would be difficult to exclude the possibility that such characters are heritable. From a practical hygienic standpoint the danger of genetic transmission cannot give the breeder much concern. Like so many of the defects named above, "blind staggers" would be reason for rejection of a reproducer, regardless of its possible influence on the progeny.

Dammann looked with a certain degree of suspicion upon the possibility of a hereditary tendency to rectal prolapses and to the dry gangrene affecting the tip of the tail in young pigs. Such defects may merely be evidence of the deterioration of the native vigor of a given breed or family as a sequel to excessive artificial selection in which the maintenance of a solid constitution was sacrificed in favor of some quality desired for purely economic reasons.

Dieckerhoff admits the possibility of hereditary transmission of a predisposition to posterior paresis (Kreuzlähme) in the horse.

Heredity and Infection.—Among the specific characters which are most constantly transmitted in genetic sequence, the susceptibility and non-susceptibility to microbic infections rank with such as body form, stature, longevity, and others which are the cardinal attributes of distinct species.

Although several species may be liable to disease caused by a single microbic species, others may be singularly exempt from such infections. Every species of animal has susceptibilities peculiar to it, and at the same time it may also manifest equally specific non-susceptibilities. These qualities are intrinsic to the genotype although not always exempt from environmental influences.

Susceptibility to a given infection is a genetic attribute always of a positive character. It is based upon such actualities as chemical affinity toward an invading, biologic form or its derivatives and capacity to supply the parasite with environment and sustenance re-

quired for its propagation. The act of satisfying such an affinity may so alter the bioplasm of the host animal as to incapacitate it for functioning in the essential processes upon which life and health are dependent. Or the interaction of heterologous and homologous biologic substances in the body of the animal invaded may mobilize the latent protective functions and thus bring into play substances which are either directly destructive to invading micro-parasites, or which behave as buffers between the two units concerned, or both. Such a protection is known as immunity, and the capacity to bring this about may also be a genotypic property.

Like susceptibility, such an immunity is a decidedly positive quality and should not be confounded with specific insusceptibility. The latter is a negative quality and is probably associated with the absence of affinity on the part of the host for the micro-organism or its products. In addition other qualities, such as temperature, hydrogen ion concentration of the body fluids, must also be reckoned with.

Susceptibility and insusceptibility must be looked upon as regularly transmitted unit characters, specific attributes of an animal species. The state of insusceptibility is the least subject to variations, if variable at all.

Horses are totally insusceptible to hog cholera and to bovine pleuro-pneumonia, cattle to glanders, sheep to dog distemper, and swine to strangles, and there is no evidence that shows that these characters have ever varied.

On the other hand, the susceptibility of certain species to microbic diseases, constant as this character commonly is, may show variability in its genetic transmission. Even in the most virulent outbreaks of specific disease there are not infrequently thoroughly exposed animals which do not sicken or which cannot be even artificially infected. Such individuals transmitting their insusceptibility as homozygotes may, in a remote future, become the progenitors of strains or breeds within a species which are peculiarly exempt from a given infection to which the species as a whole is extremely liable.

The reputed resistance to anthrax on the part of the Algerian sheep and of the zebu to piroplasmosis and other microbic diseases of the bovine species may be examples of variations in a racial or specific susceptibility. There are perhaps other instances of such a resistance to specific diseases, although in none has it been possible to establish the genetic sequence—what is known rests entirely upon empirical observations.

That such a congenital resistance to microbic infection may have a true genetic foundation was shown by an observation of Hagedoorn. It pertains to a very virulent septicemia in mice, caused by the *Staphylococcus aureus.* It was found that the common white mouse was quite refractive to this disease whereas a strain of mice originating in Japan and China was so highly susceptible that within a few days an outbreak of this infection left no survivors.

Hagedoorn had a great number of bastards of these two strains, as well as crosses between these bastards inter se and of animals bred back to the parental stock. These bastards proved to be solidly resistant in the face of a most thorough exposure. Their progeny could be divided in two groups, the refractive and the susceptible ones. Of 125 animals exposed, 34 or about one-fourth succumbed to the disease.

Further progeny obtained by breeding the bastards back to the resistant strain were entirely insusceptible, but of the 57 individuals resulting from matings between a bastard parent and the Japanese strain 32 died of the infection. Hagedoorn concluded that the resistant animals differed in their genetic constitution because they had a single gene more than the susceptible ones, and that this gene conferred protection.

In many of the instances in which hereditary resistance to infection has been assumed, its genetic origin is more apparent than real. It is not always possible to exclude previous exposure during youth as a source of acquired individual immunity, and in this the passive protection conferred by the milk of a highly immune dam may also have had its influence. In such cases genetic factors played no part as a cause of resistance to disease.

In other cases of racial immunity, hereditary factors may have been potent. It is a matter of common observation that resistant animals are always most apt to be found in regions where a given disease is enzootic. This may be accounted for by a better opportunity to acquire immunity in the manner already mentioned. Yet, consideration must also be given to the possibility that in the course of generations the more susceptible animals were rigorously exterminated by the disease and that the more resistant individuals multiplied themselves and transmitted their insusceptibility. In such a process the variation in susceptibility brought about a purification of the stock.

Hygienic Considerations.—In consideration of the very limited knowledge pertaining to the genetic transmission of defects and dis-

ease of animals it is not yet possible hygienically to direct breeding operations with exactness and effectiveness solely upon purely genetic principles. Fortunately, the selective breeding which, in a more or less empirical manner, has produced breeds and individuals of a high economic value has simultaneously tended to eliminate the stock of which the hereditary inferiority was displayed by constitutional faults.

If, on the other hand, a desirable quality was developed to such a degree that constitutional vigor became impaired or acquired an undue vulnerability, the lethal or semi-lethal tendency of such a combination of characters would, in time, check the further propagation of the defects. Such a process would, however, be so slow and so costly that skilful breeders would be apt to change their mode of procedure soon after it became apparent that they had reached the limits beyond which further refinement could not be profitably pursued.

A type of animal husbandry in which the practice of castration is a constant feature also showed a tendency to preserve for reproduction the more vigorous and sound stock. As a rule, castration eliminates the inferior animals, and this is a particularly potent factor where a practice of promiscuous and uncontrolled breeding prevails, as, for instance, under the conditions apt to be imposed on the open range. There, it has stimulated the development of more productive animals with a constitutionally sounder stock. No doubt, the introduction of superior pure-bred sires on the range has been a most important factor in the acquisition of a better type of livestock, but the systematic spaying of all but the more desirable heifer calves also had its share in the achievement. This consideration is probably the principal, if not the only, reason to justify the operation on normal animals.

Until the congenital defects are better known and their sequence in heredity is more firmly established, it will be difficult to guide breeding operations in a hygienic direction with defects alone in view.

For the firm foundation of genetic hygiene it is necessary that stud books and herd books become records of genotypic quality as well as archives of descent and genealogy. Then only will it become possible for genetics to be helpful in the prevention of diseases and defects which may be dependent on hereditary factors.

For this the breeder need not wait, because even at this time an understanding of the genetic transmission of character will be help-

ful in securing the propagation of the utilitarian qualities which he desires, and with this accomplished, the elimination of hereditary inferiority of constitution will often come about as a concomitant result.

In the selection of reproducers, defects must never be disregarded; even though they may or may not be regarded as heritable, the fact remains that not uncommonly they are corollaries of constitutional inferiority or of inadequate adaptation to environmental conditions. They are sometimes the only visible evidence of the need of challenging the quality of a breeding stock.

There can scarcely be any doubt that at least some good was achieved by means of such efforts as stallion registration, in spite of the prevailing ignorance of heredity displayed in the laws themselves. The favorable results obtained by the exclusion of unsound reproducers have been secured principally by bringing to the attention of breeders the nature of certain defects, by inducing them to become more discriminating, and hence to encourage them to avoid inferior breeding stock.

No doubt, under the operation of stallion registration laws, genetically sound animals have been rejected, for the laws are apt to specify defects merely by name and without regard to their etiology instead of prescribing inquiry with reference to their relation to genetic qualities.

It may not always be wise to base the absolute rejection of breeding animals upon the presence of a given defect. Even genetically transmitted faults may be caused to disappear from a stock by careful selection. The mating of animals with a given defect with genetically sound ones, through generations, will be apt to suppress eventually the undesirable predisposition even if its entire elimination may not always be consummated.

In the preservation of certain desirable qualities, the breeder may, and perhaps must, resort to a more or less intense inbreeding or endogamy. In such a practice the absence of genetic predisposition to defects is of more than ordinary importance. A genotypic fault in a stock of closely inbred animals will tend to accumulate to such a degree as to impair its value.

Inbreeding among animals with a sound genotypic constitution can do no harm. But the practice challenges genetic quality and in the presence of hereditary taints may be highly undesirable. Endogamy constitutes the acid test of racial superiority.

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CHAPTER III

SOIL

The intimate contact between man and the soil from which all means of sustenance were known to be derived, upon which he moved when in action, slumbered when at rest and which devoured him after death, did not fail to arouse in the earliest physicians the idea that it also might be a potent factor in his health. A relation between soil and disease gradually came to be accepted by them and their followers through the ages, although it was not until the modern era that this relation could be founded on scientific facts.

Not only is it known at the present time that the nature and surface configuration of the soil has a direct bearing on health, but also that in a number of ways it affects animal life in a more indirect manner. Such factors as malaria-breeding swamps are largely determined by soil topography; its mineral and organic constituents affect the food value of agricultural products and the character and fitness of the water supply. The nature of soil used for building sites likewise must be taken into consideration from a hygienic standpoint.

In the consideration of the soil and its hygienic relations, we can confine ourselves to the upper layers, which by their ever-changing contact with water, air, atmospheric temperature and contamination factors exercise an important influence upon animal life and well-being.

Chemical and Physical Aspects. *Composition.*—Before the crust of the earth attained its present character it underwent numerous changes brought about by causes which are by no means understood at the present time. The earliest solid surface was formed by the solidification of a preexisting hot fluid mass into stone and rocks. The disintegration or weathering of those rocks resulted in the formation of soil, and this transformation was the result of the action of temperature changes, frost, rain, flood water and wind operating during immense periods.

In the composition of the earth or soil many elements enter. Oxygen is the most abundant among them, it being estimated as constituting

from one-third to one-half of the earth's crust. Other soil elements are silicon, carbon, sulphur, hydrogen, phosphorus, chlorine, fluorine, calcium, barium, aluminum, sodium, potassium, magnesium, iron and manganese. The complex silicate of aluminum constitutes about two-thirds of the inorganic substances of the soil, and the carbonates, chlorides, sulphates, phosphates and oxides of lime, magnesium and other bases are present in considerable amounts. Nitrogen also exists in the soil in the form of protein, amino-acids, ammonium compounds, nitrates and nitrites.

Owing to the decay of vegetable matter organic acids are present in the soil, where they exercise a solvent action upon the mineral substances. Animal matter also enters into the composition of the soil by the decay of carcasses and by the deposit of animal excreta.

Formerly much importance was attached to the hygienic influence of the geologic nature and chemical composition of the soil. In the light of our present knowledge of etiology in general, these views had to be abandoned. Soil composition only exercises a very indirect influence upon animal well-being by means of the factors mentioned.

Texture.—The physical structure or texture of the soil is largely determined by the size of the soil granules, the pore space and the size of the pores. The hygroscopicity of the soil in no small degree depends upon those factors.

According to Wollny, soil may be separated into the following ingredients:

Stones more than........	10 m.m	
Coarse gravel............	10 –5	m.m.
Medium gravel..........	5 –2	m.m.
Fine gravel..............	2 –1	m.m.
Coarse sand.............	1 –0.5	m.m.
Medium sand............	0.5 –0.25	m.m.
Fine sand...............	0.25 –0.1	m.m.
Coarse silt..............	0.1 –0.05	m.m.
Medium fine silt.........	0.05 –0.025	m.m.
Fine silt................	0.025–0.005	m.m.
Colloid clay.............	0.005–0.0001	m.m.

Soils are made up of particles of varying sizes occurring in different proportions, and hence it is difficult to classify them in a very definite manner. They are often named after the particles which preponderate. When a soil possesses in about equal amounts the properties imparted by the various constituent particles it is spoken of as loam, but when a given size of particle predominates, a loam soil may be classed as sandy, clayey or gravelly.

In clay the particles are extremely small, even to the point of being no longer visible under the ultramicroscope. They are very plastic, and when rubbed together they become sticky and impervious. They are capable of remaining in suspension for indefinite periods. Clay imparts to soils heavy texture and renders them sticky when too wet, and hard and lumpy when too dry. A clay soil has a high water-holding capacity.

In the sandy and gravelly soils, there is less cohesion because of the greater size of the particles and the changes in water content exercise less influence. Their capacity for holding water is low.

The organic matter of the soil and especially that of vegetable origin is commonly spoken of as humus or organic content. It refers specifically to the primary and secondary products of decay. It increases the water-holding capacity of the soil, while its further disintegration adds to its store of plant food. It also furnishes a source of energy to the bacteria and other micro-organisms of the soil.

The open spaces found between the soil particles constitute the pores, and the relation of the latter to the former is expressed by the pore volume or pore space. It can be readily determined by the use of Whitney's formula, if the weight, the volume and the specific gravity of the soil are known.

$$S = \frac{V - \frac{W}{w} \times 100}{V}$$

S = Per cent by volume of pore space.
V = Volume of soil in c.c.
W = Weight of soil in grams.
w = S. G. of the soil.

When the apparent specific gravity thus is 1.80 and the absolute specific gravity is 2.70, the pore space will amount to 33.34 per cent. The absolute specific gravity of the soil expresses the weight of a given volume of soil particles as compared with an equal volume of water. The apparent specific gravity is determined by driving a cylinder of known volume into the ground and thus obtaining thereby a core of soil. By weighing this core and then determining the amount of water it contains, the amount of absolutely dry soil may be ascertained. The apparent specific gravity is then obtained by dividing the weight of the dry soil by the weight of an equal volume of water.

The amount of pore space is to a large extent dependent on the soil texture. The coarser the soil, the smaller is its percentage of

pore space. This relation is well shown by the following data obtained by King:

Kind of soil	Per cent pore space
Finest clay soil	52.94
Fine clay soil	48.00
Fine clay soil	45.69
Heavy red clay soil	44.15
Loamy clay soil	45 32
Clayey loam	47.10
Loam	44.15
Loam	34.49
Sandy loam	38.83
Sandy soil	34.45
Sandy soil	32.49
Coarse sandy soil	34.91

In a normal soil the pore space is occupied by water or air. When the water content is low the air content is high, and vice versa. In the deeper soil layers, the pore space is an important factor in the capacity of wells, and for the same reason it also has an influence in exposing the latter to contamination by seepage from privy vaults and similar structures.

The size of the pores, dependent on that of the granules, determines the permeability of the soil to air and water. The smaller the pores the more impervious the soil and the greater the restriction of the rate of percolation and the free movement of the air.

Surface Configuration or Topography.—The surface configuration of the soil has a more or less distinct hygienic importance, especially so on account of its relation to climate. The higher plateaux often show great fluctuations in the daily temperature, and mountain sides are apt to be constantly exposed to high winds. In narrow valleys between high mountain walls a high degree of humidity combined with quiescent air often constitute conditions unfavorable to health, and an inflow of cold atmospheric strata at night may likewise become a source of discomfort.

Surface depressions and low swampy ground may give rise to excessive soil moisture or to water accumulations which may in turn become the breeding places of certain insect pests (malaria). On the other hand, a gentle slope improves the drainage facility and thus decreases in a measure the degree of soil contamination. This, however, may be accompanied by the danger of infective materials being washed down to habitations situated at a lower level.

Owing to the difference in insolation northern slopes commonly are relatively colder than southern ones. The former often suffer from a lack of sunshine, whereas the latter may be over-exposed.

Soil Temperature.—The superficial soil layers derive their heat from four principal sources: (1) From solar radiation and the absorption of the light and dark rays. (2) From the decomposition or oxidation of the organic constituents of the soil. (3) From the precipitation of rain water of a higher temperature than the soil itself. (4) A small amount of heat is derived from the heated interior of the earth.

Heat losses are to be ascribed to: (1) The evaporation of soil moisture. (2) Heat conduction to the cooler strata below or to the cooler atmosphere above. (3) The emission of radiant heat.

The temperature of the soil is the expression of the relative influence exercised by the above-mentioned factors of heating and cooling. This influence is subject to certain modifications as may be brought about by the specific heat of soils, the amount of moisture, surface color, the degree of surface slope, tillage, texture and atmospheric conditions.

The heat conductivity of the soil is slight. It requires about one month for heat to penetrate to a depth of 5 feet. Moist as well as compact soil is more difficult to heat than a dry and loose soil, but is a better heat conductor than the latter. As a result of the slight conductivity, the temperature fluctuations become less in the deeper strata. The daily fluctuations disappear at a depth of from 20 to 40 inches, while the annual fluctuations are no longer observed at depths from 18 to 38 yards. At still greater depths the temperature of the earth increases approximately one degree Fahrenheit for every 22 yards.

The hygienic importance of soil temperature is related to its influence upon local climatic conditions and its effect upon the biologic activities of the soil. At a depth of a few feet the highest temperature reached remains below that required for the growth of most pathogenic organisms, but in hot climates or during the summer the heat of the surface may become so great that they are either greatly attenuated or destroyed outright.

Soil Air.—So far as the pore space of the soil is not occupied by water, it is filled with air. The air of the soil is a continuation of that of the atmosphere, but, owing to the fact that it is more or less confined, its movements are greatly restricted, and hence its composition is more markedly influenced by its surroundings than the

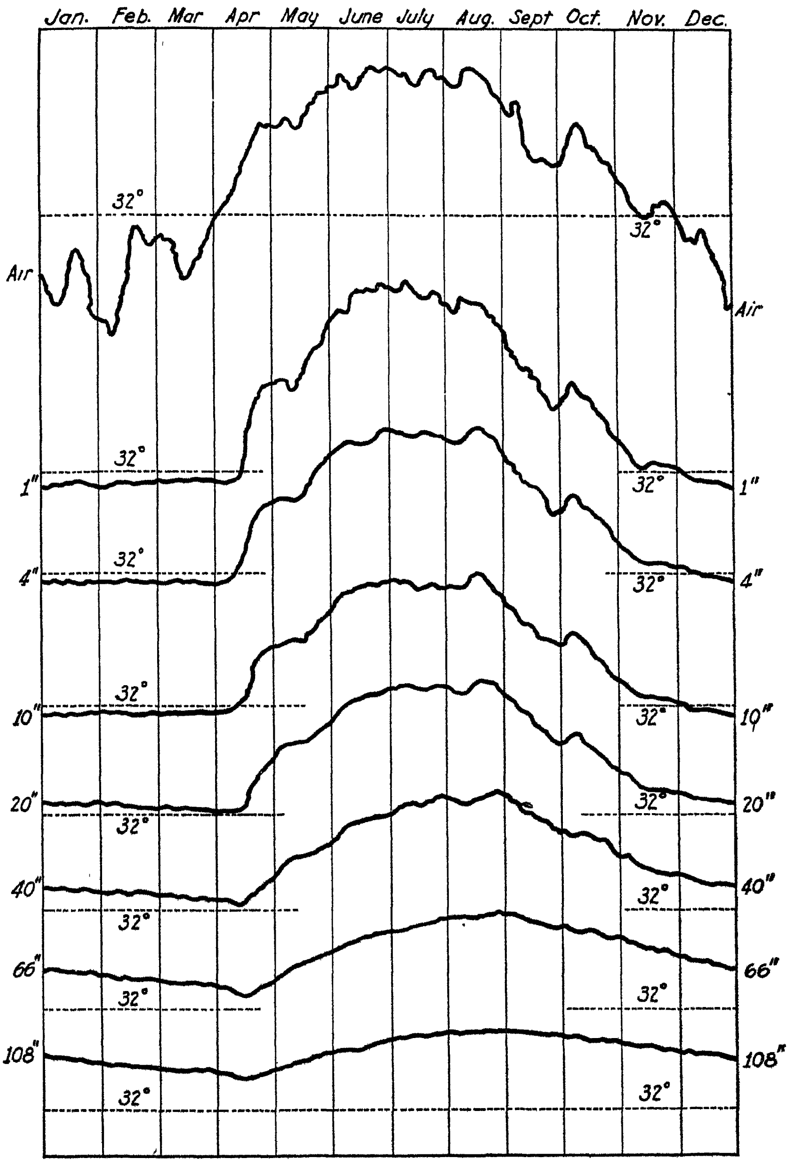

FIG. 1.—The seasonal influence on soil temperatures. (After McLeod.)

free, moving air of the atmosphere. This results in some conspicuous differences between the composition of the air of the soil and that of the atmosphere.

The humidity of soil air is always near the saturation point, it contains a greater proportion of carbon dioxide (0.2 to 14 per cent, from 2 to 3 per cent on the average), a correspondingly smaller amount of oxygen and slightly larger amounts of ammonia, methane, hydrogen sulphide and other products of the decay of organic materials.

Although the movements of the soil air are quite restricted as compared with those of the atmosphere there is nevertheless a constant movement of the air within the pore space and an active exchange of gases between it and the more freely moving air of the atmosphere.

This movement and exchange are due to such factors as difference in temperature of soil and atmosphere, the aspiration caused by winds, the movement of soil water, the diffusion of gases and changes in barometric pressure.

The soil air is always sterile; it never becomes a vehicle for pathogenic bacteria, and its hygienic influence is only in connection with the possibility of its being mixed with noxious or ill-smelling gases derived from leaks in service gas pipes or from large masses of decomposing organic substances.

Soil Moisture.—The water of the soil is derived mainly from atmospheric precipitation. This water penetrates into the superficial layers directly from the surface, whereas that of the deeper ones may have flowed over impervious layers for great distances. The amount of water penetrating into the soil is modified by the surface configuration, by the rate of evaporation, by the texture of the soil as well as by the amount of water already present within the pore space.

Water in the soil occurs in three forms: hygroscopic, capillary and gravitational or free water. Held to the surface of the soil particles by surface and molecular attraction, the former two envelop the particles as a very thin layer or film. If, after the formation of the hygroscopic film, more water is available, capillary water is also formed.

With a further increase of the latter, its weight canceling the surface tension, drops form, coalesce and gravitate within the soil substance at a speed and volume determined by such factors as temperature, pressure, texture and structure.

This gravitational water constitutes the body of ground water which is the source of supply for springs and wells. After passing a certain distance below the surface a certain level is reached where the entire pore space is filled or nearly so. When the pores are wide, the water will flow through them freely, and a well bored beneath the surface will readily fill to the level of the ground-water surface or above it owing to the pressure exercised by the superimposed soil mass. The ground water flows slowly from higher to lower levels until it finally reaches some drainage outlet, while a portion of it rises into the drier soil above by capillary attraction.

The level of the ground water or water table is not determined by the configuration of the surface, but by that of the impervious strata upon which the water rests and over which it flows.

A low water table may seriously affect the yield of wells upon which a water supply is dependent, and a high level of the ground water reaching as far up as the foundation of buildings may render the latter damp. A low level (15 to 20 feet) is commonly regarded as healthful; a high level (3 to 5 feet) is looked upon as objectionable from a hygienic standpoint. A soil with a high water table is often cold and contributes to the atmosphere near the surface an undesirable degree of humidity.

When the water table persists for long periods near the surface, the ground becomes water-logged and swampy, which promotes the development and dissemination of certain soil diseases and certain defects of the feet and hoof horn of animals at pasture. It also tends to detract from the nutritional value of the plants growing in this type of soil.

Chemical and Biologic Functions of the Soil.—The soil, so far as its upper layers are concerned, is not inert. A source of life, it is a living thing itself, owing to its many chemical and biologic functions, simple and complex. Some of these functions are intimately associated with its absorbent action toward certain organic and inorganic substances. This absorption is due in part to surface attraction and as such is largely determined by the size of the soil particles. The smaller those are, the greater the surface available for absorbent action. On the other hand, absorption must be looked upon as a result of chemical combinations in which the dissociation of double silicates plays a part in direct union of phosphoric acid and iron oxyhydrate or in the decomposition of calcium carbonate.

When soil is shaken in solutions, certain substances are absorbed, but to a less degree than by gradual percolation of the same sub-

stances through its mass. In this percolation each deeper layer receives a less concentrated solution of dissolved organic substances, members of the benzol series, protein bodies, ferments, alkaloids, etc. According to Flügge, this action may be demonstrated by very gradually pouring into a tube filled with 400 c.c. of fine sand a 1 per cent solution of strychnine, nicotin or coniin (10 c.c. per day.) After a few days the parts of the liquid drawn off at the lower end of the tube no longer contain the poisons. The absorbent action is most complete when the soil is not saturated, but when the pore space is partly filled with air or when moisture and dryness alternate. Usually the action is not confined to mere fixation, but is followed by destruction and oxidation of the organic molecules.

Every soil has it limitations for absorption beyond which it is not able to fix more substances. In such a case, the latter pass through the saturated layers to the deeper strata.

Gaseous substances are likewise retained in the soil, which attracts and fixes the gaseous molecules. The absorbent action of humus is very pronounced, and that of pure quartz is very feeble. Advantage is taken of this action in the destruction of fecal matter (dry earth closet). Likewise it is responsible for the fact that common lighting gas which escapes into the soil from leaking pipes loses its characteristic odor. It may thus lose its tell-tale features without being deprived of its poisonous principles.

The organic substances either retained by absorption or by filtration as a rule undergo decomposition, which in most cases continues until a complete destruction or mineralization has taken place. This process is spoken of as auto-purification, and although simple chemical processes, such as oxidation, are to be recognized as factors in bringing about those changes, they are to a far greater extent due to the action of micro-organisms. It is the latter which warrants the use of such expressions as "the living earth" and biologic purification.

The soil is essentially a laboratory in which is brought about the destruction of the organic substances held by its absorbent action, and in which they are preliminarily dissociated and liquefied from the surface or by the numerous species of saprophytes acting by means of their enzymes. This destruction on the whole is due to oxidation by the oxygen of the air and under the influence of a series of microbes which transform carbon into carbon dioxide, nitrogen into ammonia, ammonia into nitrous acid and the latter into nitric acid. The combination of those acids with salt-forming bases, yields nitrites and

nitrates which may again become synthesized into organic matter by the higher plants.

The number of bacteria in the soil is subject to great variations, depending on factors which either promote or retard bacterial development. In soils very rich in organic materials, this number may be very great, as many as 100,000,000 to a gram of soil having been found; in soil of ordinary fertility and tilth, the number ranges from 1,000,000 to 5,000,000 to a gram of earth. They occur mostly near the surface or in the superficial strata. Deeper down, the bacteria decrease in numbers, until at a depth of from 3 to 10 feet a soil zone free of bacteria may be encountered.

The soil layers which contain the ground water are usually free from bacteria. In exceptional cases bacteria reach the deeper layers on account of very rapid percolation of water or through such avenues as cracks or the burrows of animals.

The microscopic flora and fauna of the soil have thus far not been adequately explored, only comparatively few of the species and their functions having received attention. This is especially true of the protozoa, of which but little is known at this time. They have, however, been associated with the transportation of pathogenic elements and the ingestion and destruction of bacteria, fungi and algae.

The microscopic plants of the soil may be classed as slime molds, fungi, bacteria and algae. The larger organisms are chiefly concerned in bringing about the first stages of the decomposition of the coarser, woody materials which find their way into the soil. The bacterial species contain both aerobes and anaerobes, the former being regarded as of the greatest benefit to the soil, whereas the latter are looked upon as being more or less injurious. The structure, tilth and drainage of the soil determine the prevalence and intensity of action of the two groups mentioned.

Among the soil conditions which principally affect the growth and multiplication of the bacteria, presence or absence of oxygen, water and organic material, the reaction of the soil and its temperature are the most important. The presence of organic material above all plays a prominent part in the maintenance of the bacterial flora. As a rule, there is a parallelism between soil polution and the number of microbes which can maintain themselves in the soil and by which the biologic purification of the soil is brought about. The continuation and intensity of this process permit a great number of soils to serve in an unlimited fashion as the receptacle of organic contamination without fear of the formation of foci of dangerous insalubrity.

The destruction of organic materials must be looked upon as being due to a series of microbes which operate either simultaneously or successively. Every step in the process is ordinarily dependent on the action of several of these micro-organisms, perhaps even the action of many of them varies in accordance with surrounding conditions. It is conceivable that in the majority of cases the decomposition is not caused by a given microbic species, but is begun and continued by the action of their ferments up to a certain limit, beyond which it is carried on by the intervention of certain others.

Of the biochemical processes taking place in the soil, the ones relating to the decomposition of the carbohydrates and the nitrogenous organic materials have probably been studied the most. The former, consisting of such substances as cellulose, starches and sugars, decompose rather rapidly, principally by the action of the enzyme cytose produced by a number of fungi; the same process is probably also accomplished by *Bacillus amylobacter*. Other bacteria may likewise be involved in the production of enzymes acting on cellulose and starch. Cytase hydrolyses cellulose with the formation of sugars, and starch is converted into glucose by a ferment (diastase) either present in the plant itself or produced by the fungi or bacteria. All the sugars are finally converted into organic acids, which may combine with the several mineral bases.

Distinct organisms have been isolated which can utilize for their growths acetates, formates, butyrates, propionates and similar compounds, and dissociate their chemical construction with carbon dioxide and water as the final products. The carbon dioxide is returned to the air from which it may again be taken up by growing plants, which depend for their carbon supply upon this source. The entire process thus described is known as the carbon cycle.

The decomposition of the nitrogenous organic materials of the soil, notably the proteins, must be looked upon also as being entirely a microbic function. Among the bacteria especially involved in this action are *B. mycoides, B. subtilis, B. mesentericus vulgatus, B. janthinus* and *B. proteus vulgaris*. The *B. mycoides* has been the most carefully studied in this connection and was found to be especially endowed with oxidizing qualities. As a result of bacterial action the carbon is oxidized to carbon dioxide, the residue being ammonia and some secondary products as leucine, tyrosin, fatty acids and water. This action is favored by a temperature near 85° F., an abundance of air and a slight alkalinity of the medium.

Under further biologic influences the ammonia is oxidized to

nitrous acid (nitrites) and the latter to nitric acid (nitrates). Numerous conditions favor the action of the nitrifying ferments. Prominent among those is a free access to oxygen, which explains the favorable effect of adequate tillage, for this does away with the compactness of the soil and counteracts the choking of the pore space by excessive rainfall or irrigation. An excess of water as well as of carbon dioxide retards nitrification, but a certain amount of moisture is indispensable.

The nitrates formed are not retained by the absorbent powers of the soil. They either find their way to the deeper strata in solution with the precipitation water or are assimilated by growing plants which have no other part in soil purification.

As a result of the biologic activities of certain micro-organisms the nitrates may be again reduced to nitrites and ammonia or to nitrites and elementary nitrogen. This process is known as denitrification, but within recent times this term has been more loosely applied to any bacterial action which results in the formation of gaseous nitrogen, whether derived from nitrates, ammonia or the organic compounds of ammonia.

Some of the bacteria more specifically mentioned as causing nitrate reduction are *B. ramosus* and *B. pestifer,* while *B. mycoides, B. subtilis, B. mesentericus vulgatus* are capable of converting nitrates into ammonia. *B. denitrificans alpha* and *B. denitrificans beta* can reduce nitrates with the evolution of gaseous nitrogen.

When a lack of oxygen in the soil prevents the nitrification of the organic nitrogenous substances in the manner described, a reduction process accompanied by putrefactive phenomena takes the place of the oxidation peculiar to the former. Characteristic of this manner of decomposition is the formation of numerous fetid gaseous products and other substances, among which may be mentioned carbon dioxide, hydrogen sulphide, hydrocarbons, various amides, primary amines, leucine, tyrosin, indol, skatol, ptomaines and toxines, nitrogenous combinations which tend to persist by reason of their resistance to further decomposition.

This type of decay only terminates in very complex combinations, and in the end the organic nitrogenous material accumulates where organic matter putrefies. A little ammonia and fatty acids are formed, and if some nitrates are produced they are apt to be reduced by denitrification. There is thus a wide difference between the results of the decay by oxidation and those following putrefaction. In the first case, the organic matter totally disappears, whereas in the latter, an abun-

dance of organic detritus is formed. To a considerable extent, putrefaction is due to anaerobic microbes, which can develop in some part of the pore space in which the atmosphere is wholly or partially deprived of its oxygen.

Although it is well known that the occurrence of certain communicable diseases can be definitely associated with the soil, the part played by organisms having the soil as their natural habitat in the production of disease is by no means fully recognized. It is a known fact that some of the thermophile anaerobes of the soil are toxin producers, but until quite recently the soil-borne diseases were regarded as due to organisms which originated in the animal body and which for a shorter or longer period found a place of abode in the soil. The discovery of *B. botulinus* in virgin soils by Meyer and his associates may indicate that a true soil organism may nevertheless have an important pathogenic action.

With the possible exception of a few spore-forming microbes, to be mentioned later, pathogenic organisms are not normal or constant inhabitants of the soil, as for the greater part they succumb rapidly during the process of purification, dying in the struggle for existence. The superficial soil layers are, however, of importance enough to be given consideration when designing preventive measures against disease but only on account of the infective agents with which the soil was contaminated and in which they may be preserved for longer or shorter periods.

The Soil and Disease.—The soil itself has no qualities which may cause it to become responsible for the production of disease in a more or less direct manner. It may, as has already been pointed out, affect animal health in a roundabout way. Its influence on climatic conditions, its surface configuration affecting moisture or dryness of surroundings, its relation to the nutritive value of the vegetation it produces must be given recognition, although it is certain that those factors operate in only a very restricted manner.

On the other hand, the soil is exposed to a great assortment of contaminations which are apt to cause it to play a prominent part from a hygienic point of view. Owing to these contaminations, commonly involving pathogenic micro-organisms, the soil is a more or less constant intermediary factor in the propagation of certain diseases. Its function as such is as a rule directly dependent on the amount of contamination it receives through the excreta of diseased or virus-carrying animals, infectious carcasses, infected manure and such industrial wastes as may have an animal origin. It is probable that

all pathogenic micro-organisms at some time or other find their way into the soil and maintain themselves there with their pathogenic qualities unimpaired for longer or shorter periods. At one time it was thought that pathogenic bacteria multiplied themselves in the soil when favorable conditions such as a suitable temperature, nutrient substances and moisture were present. This view is now largely abandoned even if the multiplication of certain bacteria cannot be entirely excluded when exceptionally favorable circumstances happen to prevail.

As a rule, the strictly parasitic pathogenic organisms rapidly succumb in the soil, perish in the unequal struggle with competing soil organisms or are devoured by the soil protozoa. The surviving periods of the pathogenic organisms in the soil vary in accordance to soil conditions to such an extent that no statement could be made always valid in sanitary practice. In frozen soil where all biologic activity has ceased, a pathogenic organism is capable of surviving for many months, whereas under conditions of an opposite nature it would perish perhaps within a few weeks.

Only in the case of the spore-forming bacteria do we know that the surviving periods in the soil may be of great length. Because of this fact, they have a tendency to accumulate in a soil from which the non-spore-forming pathogens are apt to disappear under the operation of biologic purification. As inhabitants of the soil, the former tend to be permanent, whereas the latter are always transitory. This, no doubt, has much to do with the fact that nearly all the diseases commonly classed as being soil-borne are due to spore-forming bacteria.

As most conspicuous among this type of diseases, mention must be made of the ones caused by *B. anthracis*, *B. chauveaui*, *B. tetani*, *B. œdematis maligni*, *B. aerogenes capsulatus*, *B. enteritidis sporogenes* and *B. gastromycosis ovis*.

It is not certain whether all the members of this group of organisms must be looked upon as obligate parasites finding a more or less permanent resting place in the soil owing to the resistant character of their spores, or whether they are merely soil bacteria with facultative parasitic propensities. The former theory is probably correct, and this view is especially supported by the fact that the soil contents of pathogenic spore formers is the greatest in soils which through long series of years have received the most abundant admixture of animal waste matter. The frequent finding of *B. botulinus* in virgin soil by Meyer and associates may indicate that this is not

always true, although the fact must not be overlooked that this organism is not a tissue invader, and that even virgin soils cannot always be regarded as exempt from contamination of animal origin such as may be derived from wild mammals, birds or even insects.

Among the disease-producing bacteria which find a more temporary abode in the soil and which may likewise cause the latter to become a source of infection a great number have been pointed out by many observers. *B. bipolaris septicus, B. paratyphi, B. erysipelatis suis, B. tuberculosis gallinaceus, B. necrophorus, B. pyocyaneus, B. pestis, B. cholera asiatica* and *B. typhi* have been mentioned in this connection, and the virus of malignant catarrh and hog cholera are also able to find a resting place in the soil for longer or shorter periods.

The soil also serves as an abode, if not a necessary medium, for the eggs, embryos and other forms of many of the animal parasites finding their way there with the ejecta of their hosts. The highly resistant character of these forms tends to render the soil into a more or less enduring reservoir from which animals become invaded. Many species of coccidia, trematodes, cestodes and nematodes may thus be disseminated.

The infection danger associated with the soil is almost exclusively dependent on the presence of the pathogenic organisms in the more superficial layers. The ones situated in the deeper strata will, as a rule, not again rise to the surface under ordinary circumstances. They may, however, become a factor again in disease production, when the deeper earth layers are disturbed in a mechanical manner such as is incidental to construction work, ditching and other types of excavations.

The degree of infection danger offered by the soil is to a very great extent proportionate to the degree of contamination to which it is exposed. This again is dependent on the degree of concentration of animals on a given area. Although the earth of field and pasture receiving the body wastes of a relatively small number of animals, even if diseased, will offer but a relatively small infection danger, owing to the destruction of the noxious micro-organisms by the biologic activities of the soil and by the great degree of dilution to which they are subjected, the areas of soil on which proportionately larger numbers of animals are being kept continuously will present a more than ordinary disease hazard. Under such conditions there is always a more or less enduring contact with the body wastes in the presence of which no animal can exist without at some time or other being confronted with infection danger.

When disease-producing bacteria or parasites are once introduced in certain circumscribed areas serving for a numerous animal population, a vicious circle accompanied by disastrous results may be established. This is particularly seen in the case of hog lots and poultry yards, in which on account of the feeding habits of their inhabitants the closest contact with the pathogenic elements of the soil is bound to exist. In such surroundings there is no escape from an almost daily contamination of food and water with fecal matter, a circumstance which will not fail to establish a more than common disease risk. Under the conditions mentioned, the infective material is taken in simultaneously with the food, picked up from the contaminated surface or with the water accumulated on the surface. Even if the latter is not available, the water supply is readily polluted by means of the soiled parts of the body during the act of drinking.

Soil particles carrying infectious material may also be spattered upon the vegetation by means of rain or transported by flood water; or they may be transferred to the forage with the dust and thus introduced into the alimentary tract. The contamination of wounds and abrasions (including those incidental to the process of dentition) is also a common factor in the etiology of soil-borne diseases, of which tetanus, gas gangrene, blackleg and necrobacillosis are perhaps the most conspicuous examples.

In the case of certain parasitic diseases (anchylostomosis) the larvae contained in the soil adhering to the unprotected skin are capable of penetrating the latter by means of their armature.

Infected soil may be transported on the feet of man or animal, on various utensils or through the agency of insects.

The Sanitary Improvement and Sanitation of the Soil.—In the sanitation and sanitary improvement of the soil we are especially dependent on its property of self-purification. Its insalubrity is mainly due to such factors as an amount of organic waste material out of proportion to its purifying or digestive powers, a degree of stagnation of water within the pore space and a lack of free oxygen. Whatever has a tendency to remove the factors mentioned will have a definite place in soil sanitation.

The latter is especially indicated in the case of soil areas upon which a considerable animal population is maintained during longer periods. In all cases, however, the prevention of soil infection or its contamination by disease-producing agents must not be lost sight of in its relation to the maintenance of animal health. Diseased animals should be isolated on ground which is not habitually used by healthy

stock, and their carcasses should not be permitted to decay on the surface; this is particularly imperative when such diseases as blackleg, anthrax and others due to spore-forming micro-organisms are involved.

Such soil areas as poultry yards, hog lots and sheep corrals should be left periodically unpopulated in order to afford time for the process of biologic purification to be completed as well as for the subsidence of pathogenic elements to the deeper strata. This is particularly recommended for the soil areas to be occupied by young swine, which are especially liable to such diseases as paratyphus, ascariasis and necrobacillosis. A three-year rotation of such areas is advisable, and with only a slightly less degree of emphasis the same can be recommended for other animals. During the periods when such areas are not occupied by animals, the self-purification of the soil must be enhanced by tillage, cropping and drainage.

The breaking up of the compactness of the soil by tillage promotes nitrification and stimulates the biologic activities resulting in the destruction of disease-producing elements. In addition, it assists in bringing about their subsidence away from the surface and constitutes an important factor in the elimination of the less desirable anaerobes of the soil.

Tillage should be supplemented by the growing of crops on the areas involved, especially such as require a maximum amount of cultivation. The growing higher plants have a valuable part to perform in the sanitation of the soil. They synthesize many of the mineral end products of the nitrifying process and they thus tend to prevent their accumulation and to maintain a most favorable medium of growth for the soil bacteria upon which the purification process depends.

The part played by drainage in the sanitary improvement of the soil has received early recognition. By this means dangerous malaria swamps have been eliminated, low lands reclaimed and large areas rendered fit to sustain animal husbandry by bettering the quality of their vegetation. But also in a more restricted manner has the practice of drainage and especially the method of tile drainage contributed very substantially to the sanitary fitness of the soil areas occupied by domestic animals.

Drainage, by promptly removing excessive moisture, promotes the ventilation of the soil, thus increases the amount of oxygen required by the nitrifying bacteria and aids in the maintenance of the higher temperatures suitable for their growth. It permits the development of a granular structure of the soil which results in a more favor-

able condition for the absorption of water and its free circulation within the pore space. Materials having an inhibitive influence upon the bacterial life of the soil are more rapidly washed away and noxious gaseous elements are more promptly driven off under the action of the improved soil ventilation.

Subsoil drainage also encourages the transportation of such undesirable agents as parasite eggs and larvae and the otherwise indestructible pathogenic spores to the deeper layers by causing a stronger perpendicular flow of the precipitation water through the pore space. It further aids in the elimination of the surface accumulations of polluted water, so apt to be reservoirs of infection and parasitic larvae.

The disinfection of the soil by chemical means, though possible or perhaps even indicated in some special cases, as a rule is without practical value in its sanitary improvement. Aside from the enormous volume to be treated (a layer of 3 inches in thickness and an acre in area weighs approximately 500 tons), the neutralization of the disinfectant by the reducing power of the soil would tend to make such attempts extremely costly, if not entirely useless. Furthermore, if a sterilizing disinfection were possible it would also destroy the means of self-purification, the principal factor of soil sanitation.

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CHAPTER IV

AIR AND VENTILATION

AIR

AIR is the ambient medium in which most warm-blooded animals must exist, and it constitutes a most essential part of the environment in which life must run its course. Not only does it supply the substance, oxygen, which renders possible the destructive metabolism upon which all physiologic functions are based, but its constant contact with the surface of the body exercises a major influence upon the state of its well-being and helps to determine the optimum conditions under which it must function.

In nature's scheme it is one of the media of exchange which permits plant and animal life to maintain a certain balance, a depository in which the carbon required for the composition of organic substance must be received and from which it must be withdrawn before it can be utilized for that purpose.

In spite of the great volume of this exchange, air has a remarkable constancy of composition because of the enormity of the atmosphere and because of the physical influences which keep the air in constant motion.

From the earliest times, air, as an influence affecting health and disease, has played a prominent part in man's fancies, in his stock of empiric knowledge, and in his more logical deductions as its true nature and action became better understood.

Physical properties.—Air is a mixture of colorless and odorless gases, and in common with all gases possesses the qualities of compressibility and non-conductivity of heat. Though constant in composition, it may present great variations in temperature, and this, in turn, exercises a determining influence on its capacity for holding water vapor, a quality which materially influences its hygienic aspects.

Composition.—Pure air at 0° C. and at a barometric pressure of 760 m.m. has the following composition in parts per hundred:

Gases	Volumes	Weight
Oxygen	20.94	23.01
Nitrogen	78.09	76.99
Carbon dioxide	0.03	
Argon	0.94	
Ozone, hydrogen, hydrogen peroxide, helium, krypton, neon, xenon, and ammonia	Traces	

In addition, the atmospheric air contains varying amounts of water vapor, dust, and radioactive substances.

Oxygen is the constituent of the air most essential to animal life. For this it is a most imperative and constant requirement because upon it depends the combustion which is fundamental to metabolism.

Its variations in quantity in the atmosphere are so slight as to be of no physiologic importance; and even in enclosed spaces its reduction to a point below actual requirements is scarcely conceivable. Only in hermetically closed spaces would it be possible to reduce its supply to inadequate proportions by means of respiratory efforts.

Only after its amount has been reduced to 11 or 12 per cent do experimental animals begin to show evidence of discomfort or distress, and such reductions are never observed in the enclosures in which animals are being housed. Under the worst possible conditions of stabling, the oxygen reduction scarcely ever amounts to more than one per cent; and such a reduction is far less than the one encountered at high altitudes, where animals are able to live in unimpaired health. Even without taking into consideration the inherent capacity of the respiratory apparatus for accommodation to a reduced oxygen supply, there appears to be no warrant for attaching importance to such reductions as a matter of hygienic concern.

Ozone and hydrogen peroxide are present in such minute quantities as to be of negligible hygienic importance.

Nitrogen and argon must be regarded as diluents and physiologically as well as hygienically they are inert.

Carbon dioxide is a fairly stable constituent of the atmosphere. Slightly greater in amount in the air of cities or industrial centers than in that of the open country and the sea, it maintains a rather stable level. Only in the air of closed inhabited spaces or in the close

vicinity of certain sources of origin is this gas present in greater quantities.

Carbon dioxide is added to the atmosphere from different sources. It is derived from subterranean accumulations, from the combustion of fuels, from the respiratory functions of animals, and from the decay of organic matter. It is removed from the atmosphere by the higher plants, which depend upon it for the carbon required in the building of vegetable tissues, by the formation of mineral carbonates, and by its becoming dissolved in water during precipitation. The amount of carbon dioxide which plays a part in this cycle is small in comparison with the great volume of the gas present in the atmosphere, while air currents and diffusion bring about its even distribution.

Ever since this gas and some of its properties became known, it has been more or less regarded as a distinct poison. It extinguishes a flame, and animals submerged in an atmosphere largely or wholly composed of carbon dioxide would become asphyxiated or would even die as a result. There is, however, but slight reason to attribute toxic qualities to this gas, and it appears to be more in accordance with the actual facts and to be more logical to regard its action on animals submerged in it as being quite similar to that of water in drowning. In both cases we would be confronted with acute oxygen starvation and not with an intoxication. As a matter of fact, animals will live in an atmosphere which contains as much as 25 per cent carbon dioxide if the oxygen content is increased to 30 or 40 per cent.

Without the latter precaution, an increase to 2 or 3 per cent in carbon dioxide content is borne with impunity by man. When it is raised to 5 per cent, increases in respiratory depth and frequency are noted, but actual distress does not manifest itself until 7 or 8 per cent of the gas is present. With an augmentation to 10 or 12 per cent the sublethal limit is reached unless an extra supply of oxygen is provided.

Rosenau regards it as erroneous and unscientific to rely upon carbon dioxide determinations of air as the sole measure of its fitness for respiratory purposes. Furthermore, the gas never accumulates sufficiently in ordinary inhabited spaces to cause mischief. At the most it may provide a rough index of the vitiation of the air.

Horses living for long periods in mines in which there is an excess of carbon dioxide suffer no deterioration in health which can possibly be attributed to this source.

In judging the possible effects of increases of the carbon dioxide

of the air, it should also be borne in mind that, even in the atmosphere of open spaces, large amounts of carbon dioxide enter the pulmonary vesicles because with each inspiration the first air to be drawn in is that which remains over in the air passages from the preceding expiration, and this air contains about 5 per cent of carbon dioxide; at the ordinary rate of respiration this amounts in volume to approximately one-third of the air inhaled from the outside.

In a certain measure, carbon dioxide is essential to the proper functioning of the respiratory organs of the higher animals. It can be regarded as having somewhat the nature of a hormone, which stimulates the nerve centers presiding over respiration and which aids in the maintenance of regularity in action.

Hydrogen, helium, krypton, neon, xenon, and ammonia are contained in the air in such infinitesimal quantities as to be entirely without hygienic importance.

Humidity.—Although ordinarily not classified as one of the constituent gases of air, water vapor is always present in the atmosphere and must therefore be regarded as a normal ingredient. Its amount is subject to considerable variation. No normal constituent exercises a greater influence upon animal well-being, and none, under prevailing conditions, contributes more to whatever sanitary problems may be associated with air.

The capacity of air for holding water vapor is determined by the prevailing temperature, and as the following table indicates, this capacity increases with the temperature.

Temperature deg. C.	Grams of water per M^3 at saturation
−20	1.21
−10	2.52
0	4.83
5	6.75
10	9.33
15	12.59
20	17.00
25	22.73
30	30.12
35	39.30

The actual amount of vapor present in the air is designated as the absolute humidity; the term relative humidity or humidity per-

centage indicates the proportion of the absolute humidity as compared with the amount of water vapor the air is capable of holding at the prevailing temperature expressed in parts per hundred. The relative humidity may thus be expressed as follows:

$$\text{Relative humidity} = \frac{\text{Amount of vapor in air volume}}{\text{Amount of vapor at saturation}} \times 100.$$

The term saturation deficit expresses the difference between maximum (saturation) and absolute humidity.

When air saturated with water vapor is cooled, its power to contain water is reduced, and the water condenses. The temperature at which saturated air can no longer hold its water in vapor form is known as the dew-point.

Water vapor has about three-fifths the weight of air, so that dry air is heavier than humid air under equal conditions of temperature and barometric pressure.

The variations in the humidity of the out-of-door air usually range between 30 per cent or less and the saturation-point.

Atmospheric humidity affects only slightly the quality of air as far as the function of respiration is concerned, but in addition to its influence on the formation of dust and on the viability of the microbic causes of disease, it largely determines its nature as the ambient medium in which the animal body is constantly submerged.

The effect of humidity of the air is particularly associated with the part which the air plays in the heat regulation of the body. The elimination of surplus body heat constitutes a most important function in which radiation, conduction, convection as well as the abstraction of heat by the evaporation of the sweat have an essential share. Under ordinary conditions of animal life, the absence of perspiration would be followed by a rise of the body temperature if that of the atmosphere were above 21 or 22° C.; but as long as a free surface evaporation can be maintained, heat loss will balance heat production and the body temperature will be held at a more or less stable level. With an increase of the humidity, however, evaporation is reduced and heat elimination correspondingly checked. Under such circumstances, the interference with heat abstraction through evaporation is compensated for by an increased radiation, convection and conduction promoted by the increase in surface temperature through the added amount of blood in the cutaneous vessels. The heat conduction of the atmosphere is increased by humidity, which thus exer-

cises a cooling influence while its influence on evaporation has an opposite effect.

Between those more or less antagonistic influences of humidity, such factors as temperature, air movement, diet, and muscular activity become important for the establishment of either an optimum or an unfavorable condition. There is no definitely established criterion by which this optimum condition can be determined, but on empiric ground it appears that a humidity of from 40 to 70 per cent is most suitable at temperatures from 64.5 to 68° F. when the body is at rest and in the absence of air currents. At higher temperatures from 30 to 40 per cent is preferable. During muscular activity a humidity of 70 per cent at 59° F. and from 30 to 50 per cent at from 64.5 to 68° F. can be tolerated. In stables in which a humidity as high as 90 per cent may be encountered, the atmospheric condition is often extremely faulty from a hygienic point of view, and there the elimination of the excess of water vapor commonly assumes the proportion of an imperative need.

The modus operandi of heat accumulation incidental to the effects of excessive humidity and temperature is not clearly understood. They often find expression in fatigue or even exhaustion and in extreme cases cerebral and pulmonary congestion, accompanied by an increased rate of inspiration and dizziness. In the less adverse conditions of the air, dullness and impaired appetite may be the only evidences of faulty atmospheric conditions.

Sheep, quite prone to the consequences of heat accumulation, are particularly susceptible to pulmonary congestion and pneumonia under such circumstances.

It is a common belief that animals in offensively humid enclosures are more apt to become infected with certain transmissible diseases; a considerable amount of evidence supports this opinion.

Impurities.—The lower strata of the atmosphere constantly receive a great variety of foreign substances. They constitute the impurities most frequently encountered in inhabited places, where the products of combustion, organic decay, and industrial wastes are more or less continually discharged into the air, and where finely divided solid materials of multiple origin find their way into the air where they remain in suspension for shorter or longer periods.

According to their physical character, the impurities of the air may be classified as gaseous or diffused, and solid or suspended.

Gaseous Impurities. *Ammonia.*—A product of organic decay, ammonia is always present in the atmosphere. Owing to its great

dilution in the out-of-door air, it is without hygienic significance in that situation. In closed stables where nitrogenous body wastes (urine) are apt to accumulate and decompose, it commonly forms in appreciable quantities (0.05 to 0.1 per cent). Under certain conditions its quantity may increase to a point where it irritates the mucosa of the eye and the upper air passages.

Although there is no evidence that a prolonged exposure to such an atmosphere results in definite pathologic conditions, there is ground for the belief that certain types of virus may more readily find entrance through the surfaces so exposed. A notable presence of ammonia in the stables, furthermore, must always be regarded as evidence of faulty indoor air conditions.

Hydrocarbons in the form of marsh gases find their way into the atmosphere, but are without importance because diffusion and the effects of air currents prevent an accumulation in sufficient concentrations to do harm.

Carbon monoxide is the result of the imperfect combustion of carbon. It is present in considerable quantity in the exhaust gases of internal-combustion motors and is a constant ingredient of illuminating gas. It is highly toxic, owing to its property of entering into an enduring combination with the hemoglobin, rendering it incapable of serving as a carrier of oxygen. The inhalation for one hour of air containing 0.4 per cent of this oxide may have fatal results; a more chronic intoxication by air containing a smaller quantity is liable to produce anemia and a series of functional disturbances associated with this condition.

Carbon monoxide poisoning is not common in animals, although deaths from that source have been recorded. With the universal use of gasoline motors, the danger associated with the discharge of exhaust gases into closed spaces must, however, be reckoned with.

Sewer Gases.—They are largely composed of the gaseous products of putrefaction and were at one time seriously regarded as factors in disease production. They are no longer so considered and can be dismissed as being without influence upon animal health.

Sulphur Dioxide.—The formation of this gas accompanies the burning of coal, and it is also set free by smelters and other industrial establishments. Aside from accidents incidental to the use of the gas in the practice of disinfection or deratting and during its application as an acaricide, it has no sanitary significance.

Smelter gases containing lead, arsenic and zinc do not occur in the air in sufficient concentrations to harm animals inhaling the air

so contaminated. The sublimination of those heavy metals on forage crops and pastures may, however, become a source of danger to animal health.

Toxic Substances of an organic nature and assumed to be eliminated from the animal body by expiration and evaporation from its surface have been regarded as factors rendering the air in enclosed spaces particularly offensive and as being largely responsible for its depressing effects. That certain gaseous ingredients, even in too small an amount to be determined by analysis, can render a confined atmosphere esthetically offensive to man there can be no doubt. Intestinal gases and the odoriferous emanations from the mouth and upper air passages caused by tooth decay, ozena or metabolic disturbances may all have a highly nauseating effect. This may be too subtle for analysis, but there is no evidence that they play a direct depressing part on animal health. The same can be said of the hypothetical fatigue poison which, along with "sewer gas," has been and is occasionally yet mentioned as a valid reason for the aeration of inhabited spaces.

Solid Impurities.—Finely divided substances of an almost endless variety find their way into the atmosphere as a result of desiccation and air currents. Suspended particles of solid matter are always present in the air outdoors as well as indoors. In the latter they frequently constitute a problem of the industrial hygienist. Their importance in livestock sanitation has not the same magnitude, even if they cannot be entirely dismissed as hygienically insignificant.

Inorganic or mineral as well as organic and biologic particles are found to occur in the air in a state of suspension. They constitute the dust of the atmosphere.

Inorganic or mineral dust derived from the soil, from the surface of the sea, and from interplanetary space includes calcium salts, silica and silicates, sodium, chloride, iron oxide, magnesia and other substances, to which must be added volcanic dust and, in certain localities, a not inconsiderable amount of the carbon which as soot is discharged into the atmosphere with smoke. Though frequently a manifest nuisance, the dust supplies the surfaces essential to the condensation of water vapor and thus causes precipitation as rain or aids in the formation of clouds and fogs.

Most of the mineral dust is innocuous to animals, and a dust problem such as is furnished by many industries does not exist in the hygiene of animals. Reports of damage by inorganic dust are uncommon in veterinary literature, the most notable case recorded being

one of lead poisoning of the horses in a riding establishment in which the ground had been covered with the sand of an abandoned lead working. In this case, the dust raised from the surface by moving animals was inhaled and swallowed with the saliva and brought about the intoxication.

Organic dust consists of desiccated particles of animal and vegetable origin. It includes particles of dried feces, starch, pollen, spores, seeds, plant cells and fibers, epithelial scales and other cuticular débris, scales of the wings of moths and butterflies, hairs, feathers, bits of tissue and other parts. Most of this material is lifeless, but among the organic impurities of the air are also found bacteria, molds and fungi, algae, rotifers and other biologic forms.

The lifeless organic material which enters the air as dust is largely harmless in nature. Dust particles may become vehicles of microbic disease producers, but *per se* they do not appear to have a great hygienic importance.

It is not certainly known that the diseases due to hypersensitization of the various mucosa by dust containing protein substances are prevalent among animals as they are in man. Something like hay fever, however, has been described in horses; and there may also be some ground for the popular belief that dusty hay plays a part in the causation of pulmonary emphysema or "heaves." In such a case the possibility of a hypersensitization influence cannot readily be dismissed. In the etiology of the pulmonary mycoses of birds, the spores of the molds responsible may be conveyed to the organs involved as a component part of the dust of the inspired air.

Stable dust plays an indirect, although a very important, part in stables in which milk is collected or handled. Owing to the bacterial contents of such dust, the keeping quality of the milk is potentially influenced by being exposed to it, aside from the possibility of such pathogens as the tubercle bacillus gaining entrance in the same manner.

Bacteria.—Since ancient times, the air has been regarded as a potent factor in the dissemination of animal diseases; and after the discovery of microbic origin of many diseases, the air, for a time, was looked upon as a most ready means for the distribution of disease-producing organisms. After a better understanding of the nature of the transmissible diseases had been acquired, the earlier views underwent a marked modification. So far as the out-of-door air is concerned, its part in the transportation of the biologic causes of disease is no longer recognized. Indeed, such transmission must be rare,

if it occurs at all. The enormous degree of dilution under the influence of space and air movements is well-nigh fatal to infection possibilities.

At the most, micro-organisms would remain in a suspended condition for very short periods; also, the action of light, oxidation and the alternation of dryness and humidity would prove to be greatly adverse to the continued life of obligate micro-parasites found in a situation for them entirely abnormal. In the air of enclosed spaces, however, such as of stables, the possibility of its playing a part in the transmission of disease must be more seriously considered; but even there certain factors must cooperate in order to bring about actual infection. In an indoor atmosphere, the effects of dilution, of sunlight, and of desiccation are largely canceled, and with the presence of one or more infection sources, diseased animals, a greater concentration of infective material may and commonly does take place.

Important in this connection is the spraying of virulent liquid excretions through such acts as coughing and sneezing. The droplets containing the microbic pathogens may thus be projected into the atmosphere in which they may remain suspended for a time. In that position they may be inspired by other animals in close proximity or eventually be deposited on food or drink.

Bacteria discharged with the feces or urine may in turn gain the atmosphere attached to dust particles and, by them transmitted to animals, or adhering to the body surface, they may be suspended in the air for longer or shorter periods in connection with the cuticular débris commonly detached from the animal body.

Thus, on the whole, air may be regarded as being without great importance as a vehicle for infection, with the exception of that contained in enclosed spaces in which diseased animals are actually present within a definite period.

VENTILATION

Out-of-door Air and Stable Air.—It has been noted that the composition of the out-of-door air is not subject to changes to which a hygienic significance can be attributed. Only the adjuvant water vapor is subject to change, and this is quite intimately associated with the temperature.

Temperature as well as humidity affect animal well-being, but their fluctuations in the out-of-door air are seldom of such a nature that they cannot readily be compensated for by the adaptibility with which the animal body is so admirably endowed. As a general rule, the latter will normally adapt itself to whatever changes may occur in humidity and temperature of the outside air.

If the air, on the other hand, is confined in inhabited enclosures such as stables, it gradually becomes altered, and its chemical composition as well as its physical aspects may come to differ quite substantially from those prevailing outside. The influences of dilution, diffusion, and air movements are to a large extent canceled for the indoor atmosphere; moreover, the respiratory utilization of the air not only changes the proportion of its chemical constituents, but also adds to its humidity. The latter is further augmented by the evaporation from the body surface and from the liquid body wastes.

As an additional factor in the alteration of a stable atmosphere must be mentioned the gaseous end products of the decomposition of the organic substances of feces, urine, and bedding materials. At the same time, the water-holding capacity of the air is enhanced by the increase of its temperature through the heat produced by the animal body; and this change likewise cannot fail to be without physiologic importance.

In the consideration of air in its hygienic aspects, therefore, a distinction must be made between the out-of-door air and that of enclosed spaces, inasmuch as the latter is apt to place a greater burden on such powers of adaptation as the animal body may be able to exercise in the face of a changed atmospheric environment.

Air Changes in Inhabited Spaces.—In enclosures in which the air is subjected to respiratory changes there must obviously come about a marked alteration in the proportion of at least some of its constituent gases, provided that communication with the outside atmosphere is eliminated. The degree of change is manifest when the amount of oxygen consumed and that of the carbon dioxide produced is given consideration.

In a computation exhibited by Ellenberger and Scheunert the following amounts are submitted.[1]

[1] Ellenberger und Scheunert, Lehrbuch der vergleichende Physiologie der Haussäugetiere, 3 Aufl. (pr. 25 M.), by permission of Verlag von Paul Parey, Berlin, S. W., 11.

GAS EXCHANGE PER KILOGRAM PER HOUR

Animal	Oxygen consumption in c.c.	Carbon dioxide production in c.c.
Horse	253	241
Cattle	328	320
Sheep	342	341
Swine	392	336
Dog	911	674
Fowl	739	714

Thus in a horse weighing 500 kilograms there will be utilized in 24 hours approximately 112 cubic feet of oxygen, and during the same period about 107 cubic feet of carbon dioxide will be given off.

It is conceivable thus that, if the available volume of air is sufficiently breathed and rebreathed in a closed space, there must in time result an atmosphere which for lack of oxygen and a corresponding increase of the carbon dioxide is no longer capable of sustaining life.

However, such a change can be brought about only under extreme, usually experimental, conditions, and the changes mentioned are scarcely ever attained in enclosures such as those commonly used for the stabling of animals. Even when a stable space was deliberately constructed with a view of bringing about a maximum of air vitiation, it was impossible so to change the air as to make it insufficient for respiratory purposes. In the experiments of Reynolds and Lipp in which this was attempted, the carbon dioxide content was not raised above 2.67 per cent (or 89 times that of normal air), and when the closed stable conditions were very bad the percentage would range between 0.52 and 1.09 (from 17 to 36 times that of fresh air); even this extreme degree of deliberate vitiation was not capable to cause respiratory distress.

A vitiation expressed by a carbon dioxide content of from 0.8 to 1 per cent cannot even be recognized without recourse to analytical methods.

The utilization of stable air results in changes in the oxygen and carbon dioxide contents; also the presence of animals increases the humidity, and as the water-holding capacity of the air also increases under the effect of temperature a pronounced alteration of the ambient atmosphere must in time come about. This change of air condi-

tions is apparently not so readily overcome by the avenues open to carbon dioxide and oxygen for communication with the outside, and hence water vapor is more apt to accumulate in stables.

The amount of water eliminated by the animal body corresponds roughly to that taken in as drink, that which is contained in the food, and that formed as metabolic water. Not all of this reaches the atmosphere, for a good part of it is removed by stable drainage or remains contained in the bedding, feces, etc.

The water eliminated from the lungs and skin is the principal source of the humidity of the air. Smith estimates that a horse at rest gives off from the skin and lungs about 6.4 pounds of water during 24 hours. This amount of water in the vapor state would, at the constantly maintained temperature of 68° F., be sufficient eventually to bring about a saturated humidity of a space of approximately 6500 cubic feet, provided that all condensation and communication with the outside could be prevented. Under actual stable conditions such extremes but rarely occur, even if under exceptionally bad circumstances the saturation-point is occasionally closely approached.

As further changes in the gaseous contents of inhabited closed spaces must be mentioned the addition of ammonia, principally derived from the decomposition of urea, of intestinal gases, and the emanations from the body surface, all of which, though not materially changing the air in its hygienic aspects, often constitute the most appreciable evidence of vitiation.

Stable air is commonly rich in suspended impurities in the form of dust detached from the forage, hay, bedding, of desiccated fecal matter, or dried débris shaken from the body surface. Stable dust, as a rule, contains many biologic elements, such as molds, fungi and their spores as well as bacteria. Droplets of the liquid secretions may also be projected into the atmosphere during coughing and sneezing, and in the presence of specific infections their bacterial contents may acquire a real hygienic importance.

The air of closed inhabited spaces always differs from that out of doors, nor is it comparable with the atmosphere present in enclosures hermetically closed for experimental purposes or as a result of accident; but many factors contribute toward defining the relative position occupied by the stable atmosphere with regard to the two extremes mentioned. Air movements, temperature differences, diffusion, the nature of buildings and building materials, the number and kind of animals, etc., all play their parts in determining or modifying the difference between inside and outside air.

Physiologic Considerations.—Inasmuch as the housing of animals in more or less closed stables is a general practice, it becomes useful to consider briefly the physiologic importance of the differences that may be found to exist between the air inside and that out of doors.

For a long time, the reduction of the oxygen and the increase of the carbon dioxide were accepted as changes of paramount physiologic importance; and even now those alterations are often found to be dominant when stable air is hygienically considered. It is especially the carbon dioxide content which is accepted as the criterion of air quality.

Those ideas continue to persist, although as far back as 1883 Hermans reported carefully conducted experiments which to a large extent disproved the physiologic importance attached to the air changes mentioned. He showed that even a reduction of oxygen to 15 per cent and a simultaneous accumulation of carbon dioxide to 4 per cent had no deleterious effect on the persons who were subjected to the experiment.

Some years later, Flügge, Paul, and Erklentz confirmed Hermans' results. In all these experiments, as well as in the later ones by the New York Commission on Ventilation, the effects of real or supposed organic emanations from the human body were likewise found to be of no physiologic or hygenic importance.

Reynolds and Lipp, who experimented with steers, arrived at the same conclusions, and as a result of their investigations, they felt warranted to state that the amount of carbon dioxide present under any probable conditions of stabling or any probable lack of oxygen is not seriously important; and that in addition the amount of carbon dioxide present in an atmosphere is a very unreliable guide as to the hygienic condition of the stable or even of the air alone.

All evidence based on experimental inquiry shows that whatever may render vitiated air oppressive or physiologically inadequate is not associated with a reduction of the oxygen or with an increase in the carbon dioxide, and that the assumed influence of any organic poison could likewise be canceled as unimportant.

In regard to ammonia, Reynolds and Lipp, though admitting that a given amount may become disagreeable or even slightly irritating to certain mucosa, found nothing to indicate its harmfulness when present in quantities which may accumulate under actual stable conditions.

The well-known depressing or even harmful effects of a vitiated

air thus cannot be explained by the chemical changes taking place in a confined atmosphere.

The earlier workers such as Hermans, Flügge, and others who challenged the theory of the purely chemical action of vitiated air had already called attention to the importance of the humidity factor; and this importance was in more recent times quite definitely confirmed by the investigators of the New York Ventilation Commission, by Hill, and by other workers, so that, in the light of our present knowledge, the influence of humidity and its concomitant temperature appears to be dominant in the problem presented by vitiated indoor air.

These influences are particularly exerted on the heat-regulating function of the body by modification of the degree and promptness of heat elimination. In the body of the homoiothermic animals, the component cells and tissues require an optimum temperature for the adequate performance of their functions, and this degree of temperature is controlled by the reciprocal action of heat production and heat loss. This compensating or balancing action is, however, subject to certain limitations; and when they are exceeded, disturbances in metabolism and in the state of normality are apt to assert themselves.

With increase of the humidity and the temperature of the ambient air the outgo of body heat becomes checked, and when this retardation of heat loss takes place there may come about a heat accumulation which cannot always be sufficiently prevented by a compensating inhibition of heat production. In the more extreme instances of heat accumulation, this results in what is known as "heat stroke," during which the temperature to which the various tissues are subjected may approach or actually do attain a lethal point. This point has been fixed with a considerable degree of accuracy at from 113° to 115° F., temperatures which owe their destructive quality chiefly to their action on the myocardium.

The pathology of acute heat stroke or so-called heat exhaustion is fairly well understood; but practically nothing is known of the effects of sublethal degrees of heat accumulation which, under conditions of repose, may come about in stables in which a high temperature and a high relative humidity retard the elimination of excessive body heat, and which, consequently, may make heavy demands on the power to compensate with a reduced heat production.

That the factors mentioned exert an influence on animal well-being has been empirically known for a long time, although they were commonly associated with air changes of a chemical nature. In more

recent times, experimental results showed that indeed all discomfort and inefficiency of persons exposed to bad indoor air conditions can be attributed to them. Nor can it be doubted any longer that the depression, dullness, and inappetence shown by animals exposed for considerable periods to vitiated stable air can be traced primarily to interference with the required degree of heat elimination by the combined effect of humidity and temperature.

Hygienic Importance.—The data gathered in the practice of animal husbandry point toward the fact that with certain limitations, largely associated with inclement climatic conditions, the out-of-door air is best suited to normal animal life.

Not only is the animal body, by its compensatory functions in regard to heat regulation, better able to adapt itself to changing conditions of atmospheric temperature and humidity, but the effect of air movements and the exposure to direct solar radiation are also factors in the maintenance of a normal state of health. In the stable, more or less a necessary evil, the alteration of the ambient atmosphere for the reasons already stated makes a higher demand on the body's capacity to adjust itself to those changes.

The modus operandi by which a vitiated air acts in a depressing manner on body functions may not be well understood in all its details, but in the face of a volume of knowledge empirically acquired its unfavorable influence cannot be denied. This influence cannot be accurately measured in terms of health; but observations of slight, although significant, increases in the yield of milk or eggs when cows or fowls were subjected to improved air conditions are no doubt indications that certain body functions, at least, were strengthened by their influence.

It is an accepted theory among livestock sanitarians that stabling under adverse air conditions favors the propagation of certain transmissible diseases, and many observations could be cited in its support. This is commonly believed to be due, in part at least, to the depressant action of foul air on the defensive qualities of the body.

Although one should be exceedingly careful in arriving at conclusions based upon opinion rather than on recorded facts, the theory that foul air may invalidate the body defense against disease may have acquired some foundation as a result of experiments by the New York Commission on Ventilation.[1] Experimenting with rabbits,

[1] Ventilation, Report of the New York State Commission on Ventilation (C.-E. A. Winslow, chairman), by permission of the publishers, E. P. Dutton & Co., Inc.

it was found that the formation of hemolysins in the blood appears to be delayed by the exposure of the animals to an atmospheric temperature of 86° F. as compared with control animals kept at a temperature of 68° F. The difference between the two groups persisted for three weeks, but from the fourth week onward the hemolytic power of the blood was approximately the same in the two groups of animals. Wide variations in individual cases were, however, observed; and out of a total of twelve animals exposed to the higher temperature, four failed to show the delayed reaction.

Four out of five series of rabbits tested for the formation of agglutinins showed a less active development of agglutinating power in animals exposed to an atmospheric temperature of 86° F. as compared with animals kept at 68° F. The differences were slight but appeared to persist for at least four or five weeks.

Respiratory infection of rabbits with *B. bovisepticus* appeared to be definitely favored by chilling the animals to from 20° to 56° F. after keeping them at temperatures between 63° and 90° F. A change from a low temperature of 50° to 59° F. to a high temperature of 77° to 80.5° F. seemed even more harmful in its effects.

Aside from a reduction in the resistance to disease brought about by a continued exposure to foul air, there are other factors which favor disease transmission. In the presence of an infection hazard such transmission is apt to be less potent in the out-of-door air as compared with the atmosphere found in stables even without vitiation. The greater concentration of infective materials in enclosed spaces and the closer propinquity of the animals are important factors, but it is also a well-established fact that under the influence of a humid, quiescent atmosphere the infection chances are materially enhanced.

Dampness of stables and air vitiation are furthermore favorable to a more durable viability of many microbic pathogens, and also the exclusion of the organism from the action of direct solar radiation must be credited as a means by which their chances of survival may be increased.

Such diseases as tuberculosis, glanders, strangles, mycotic pneumonia, hog flu, infectious horse pneumonia (Brustseuche), contagious pleuro-pneumonia, foot and mouth disease, mastitis, and even wound infections not only are more readily transmitted under the influence of a vitiated atmosphere, but several of them apparently are apt to assume a more malignant character in animals stabled under the adverse conditions mentioned.

Ventilation.—The air changes which take place in more or less closed stables occupied by animals, their effect on certain physiologic functions, as well as the general hygienic importance of a pure air are held to be sufficient reasons for efforts to reduce to a minimum the unfavorable influences exercised by air vitiation.

Such efforts consist in replacing a given volume of altered indoor air by an equal volume of outside air, in creating sufficient air movement to free the body surface from its surrounding layer of heated humid air, and in bringing this about at such a rate that animal comfort be not unduly interfered with. The air exchange involved in those efforts is designated as ventilation. The need for it is particularly confined to sections and seasons, where and when inclement climatic conditions render close stabling necessary. In warmer climates or during the summer months of the moderate zones, when stabling merely consists in furnishing overhead shelter, a ventilation problem does not exist.

The function of ventilation thus consists of, first, the removal of humidity and excessive temperature; second, the removal of diffused and suspended impurities; third, the maintenance of a certain degree of air movement, and fourth, the accomplishment of these tasks by bringing about the influx of an amount of outside air at a rate commensurate to the volume of vitiated air removed.

Ventilation, however, cannot bring about out-of-door atmospheric conditions within a stable if animal comfort is to be preserved under all circumstances. It is above all expected to do away with the degree of vitiation which is apt to cause interference with adequate heat regulation of the body which cannot be neutralized by the compensatory action that normally helps to maintain the optimum temperature required for the performance of the metabolic functions of cells and tissues. As Rosenau has it: "The art of ventilation consists in adapting indoor conditions to indoor life."

Ventilation Requirements.—Many attempts have been made to define more or less precisely the required volume of air exchange. Formulas have been searched for, indeed, actually constructed and used in the guidance of ventilation practice, and yet definite specifications can be laid down only under exceptional circumstances. To a very considerable extent, empirically acquired knowledge and the observation of actual stable conditions must be given weight in the solution of ventilation problems, which nearly always have a more or less local or individual character.

This is largely due to the fact that air movements in and out of

stables are ordinarily entirely associated with such atmospheric qualities as temperature, humidity and wind. These factors are never constant, and, though calculations may be based on prevailing averages, they can only meet the fleeting conditions part of the time under ordinary stable conditions. It is mainly for this reason that perfection in stable ventilation has thus far remained somewhat of an unrealized ideal.

With the changed views in regard to the manner by which air vitiation may affect animal well-being, the theory upon which certain calculations were based is no longer tenable, even if those formulas have not altogether been deprived of all usefulness. They are designed, at any rate, to bring about a certain exchange of air, and this also is a requirement in the light of more correct later knowledge of the subject. On the whole, it appears to be exceedingly difficult to apply mathematics to the solution of ventilation problems.

Carbon Dioxide.—It has already been pointed out that the carbon dioxide output of respiration and of organic decay in stables was for a long time regarded as the principal reason for the ventilation of inhabited closed spaces.

Ventilation designs and specifications were based on the amount of carbon dioxide to be eliminated. As the amount of carbon dioxide permissible in stables was arbitrarily estimated by various authors, the volume of air exchange demanded by them showed marked variations, and those differences did not tend to simplify the ventilation problem.

Märcker estimated that a stable air with from 2 to 3 parts of carbon dioxide per thousand parts of air can still be regarded as good; that when 3 parts per thousand were present, the air was spoiled; and that 4 parts per thousand was the very limit which could be tolerated.

Largely basing his conclusions on Märcker's estimates, Klimmer concluded that a cow requires about 1650 cubic feet of air per hour as a minimum, but that as much as about 2600 cubic feet may be desirable. Smith calculates that the large herbivora require 15,000 cubic feet per hour. Linton, more elastic in his requirements, places the air needs of a horse at from 5000 to 15,000 cubic feet per hour. Armsby and Kriss, using King's computations as to respiration and ventilation requirements, estimate that the air exchange for horses may be placed at 4303 cubic feet per hour, for cows 3545 cubic feet, for swine 1394 cubic feet, and for sheep 909 cubic feet. Schlossmann, who demands that the carbon dioxide content of stable air

do not exceed 1 part per thousand, places the air requirement per cow at about 5550 cubic feet per hour. Mackenzie and Russell say that a poultry house should not contain more than 9 volumes of carbon dioxide in 10,000 volumes of air, and that each bird should be allowed 40 cubic feet of air per hour.

As more recent studies of air vitiation have shown that the amount of carbon dioxide present in an atmosphere is a very unreliable guide as to the hygienic conditions of the stable, it can be safely disregarded as a base for ventilation calculations. At the most, the carbon dioxide content may be considered if a question of ventilation mechanics has to be solved, but not as a criterion to animal comfort or well-being. When other ventilation requirements are met, the carbon dioxide factor will automatically take care of itself.

Humidity.—On account of the part played by humidity in the bringing about of a depressing influence in air vitiation, its removal must be regarded as a most important objective of stable ventilation. Owing to the many variable factors which enter into the problem, it is probably impossible to establish any fixed rule by which ventilation requirements with reference to humidity can be determined with any degree of exactness.

King has published the following estimates intended to be of service in the prevention of the condensation of moisture in stables:

Required Number of Cubic Feet of Air per Hour per Head to Prevent Condensation of Moisture When It Enters the Stable 75 Per Cent Saturated and Leaves It Saturated at the Stable Temperature

If the air is 75 per cent saturated at the temperature of: °F.	The volume of air per head and per hour must be in cubic feet when the stable temperature is:				
	30°	40°	50°	60°	70°
−10	1 788	1.164	792	540	394
0	1.982	1.253	832	554	402
10	2.334	1.385	887	569	415
15	2.620	1.489	931	614	424
20	3.140	1.634	996	638	434
30	6.228	2.201	1.165	715	466
40	.....	4.268	1.566	842	520
50	.....	.....	1.782	1.126	655

King's estimates are of value for purposes of comparison, but as they imply a saturated humidity within the stable, the volume of air movement must fall short if an atmospheric condition conducive to animal comfort is to be maintained. Double the amounts named in the table will probably be nearer those actually needed.

As already stated, estimates largely arrived at by empiric considerations indicate that a probable optimum condition prevails when, with temperatures ranging between 64° and 68° F., there is a relative humidity of from 40 to 70 per cent. As the temperatures mentioned are, no doubt, higher than those commonly desirable, a higher degree of humidity combined with lower temperatures would probably not be accompanied by depressing effects although this combination may be conducive to chilliness.

Temperature.—In the consideration of ventilation requirements the question of humidity cannot be detached from that of temperature; in addition, the temperature is a factor in animal comfort as well as one to be included among the forces which bring about air movement.

It appears, however, that in stables in which the available space is commensurate with the number of animals, the amount of heat produced is sufficient to permit an adequate volume of air exchanges; the prevailing temperature suitable for animal comfort, as a rule, need not to be as high as that required in human habitations.

The heat production in inhabited stables has been calculated by King, who published the following data:

Approximate Temperature of Stable Air Resulting from Animal Heat, When Entering at Different Temperatures at the Rate of 3542 Cubic Feet per Hour per Cow

Temperature of outside air (°F.)	Temperature of inside air (°F.)
−32	15.55
−10	37.55
0	47.55
10	57.55
15	62.55
20	67.55
25	72.55
30	75.55

As has been pointed out by Armsby and Kriss, the temperature requirements are not the same for all animals. There is a certain external temperature, called the critical temperature, at which heat loss is just balanced by heat production. Under the influence of diet this critical temperature may be higher or lower; heavily fed animals, for instance, can withstand cold better than those kept at a maintenance ration. In horses the critical temperature is higher than in cattle, and that of swine also is comparatively high. Sheep occupy an intermediary position. Cattle thus can be exposed to lower temperatures before the food requirements will be affected.

These authors deem it desirable that on the one hand the surrounding temperature should be low enough to maintain the appetite, but on the other hand not so low as to cause a wasteful consumption for the mere purpose of heat production.

On the whole, it appears to be well established at this time that, for well-fed animals, the need of warm stables has in the past been somewhat overemphasized.

The same opinion is expressed by Speir, who states that any saving of food costs by keeping the animals in a warmer environment is equaled, if not exceeded, by an improved digestion, when they have plenty of fresh air, but of a lower temperature. He believes that too high a value was placed on heat and too low a value on fresh air. The latter is a much more important factor in the production of milk in mid-winter than is generally believed. Making his observations in Scotland, he deems it hopeless to be able to keep the air in any cow stable at from 60° to 63° F. during the ordinary winter without excessive pollution of the air. In order for the animals to meet winter conditions he recommends that their ventilation should not be restricted in autumn, so that they may retain or even increase their hair coat.

Curot counsels the maintenance of a stable temperature between 53.5° and 64.4° F. for horses and cattle, and between 50° and 53.5° F. for sheep, and not lower than 59° F. for swine.

Douglas recommends that the temperature of a cow stable should always be kept down to 50° F. if this can be done without creating drafts. In his opinion any restriction of ventilation sufficient for raising the temperature up to 60° F. leads to a degree of atmospheric impurity inconsistent with conditions of perfect health; and whatever waste of food may be entailed in the maintenance of body heat of the cows in the colder stables is more than counteracted by the influence of better air conditions.

In regard to horses, Smith states that whereas hot stables produce a fine glossy hair coat, economize feed, and promote fattening, they also render the animals more susceptible to disease. He adds that it has never yet been shown that unlimited fresh air in cow stables either seriously retarded fattening or milk production, if the animals concerned were liberally fed.

According to King, it seems likely that the best temperature surroundings for highly fed animals will be found to be between 45° and 50° F., and animals on a maintenance ration will be found to do better and to be maintained at a lower cost at temperatures between 55° and 65° F. For dairy cows with large udders and with a scanty hair coat, it may be expected that a temperature as high as 50° to 60° F. will be found best even with high feeding. Higher temperatures than the ones mentioned may need to be provided for newborn or very young animals, even if a certain degree of restriction in the air exchange of the stable is necessary to bring this about.

From the data submitted by various authors, it is apparent that, although there is no agreement in regard to precise temperature requirements, the general trend of opinion is that the conservation of the stable temperature should not result in a restriction of ventilation to such a degree that the stable air may be markedly vitiated, and also that a possible higher feeding cost in a ventilated, cool stable is more than compensated for by improved living and health conditions.

Air Space and Ventilation.—The amount of cubic space allotted to each animal in a stable is connected with the ventilation problem only by the fact that it determines to a large extent the number of times per hour the air can be changed without producing disagreeable drafts. The smaller the space, the oftener must the air be renewed in order to eliminate excessive temperature and humidity. The greater the space, the more difficult will it be to prevent undue chilling during the coldest periods of the year. In addition, the factor of increased construction cost must also be given consideration.

Like in all other details pertaining to ventilation, there is a considerable diversity of opinion among various authors on the subject of cubic space and air turnover in stables. If the subject is carefully considered with due regard to what is experienced in actual ventilation operations, it appears that a space of from 40 to 60 cubic feet for every hundred pounds of live weight should be available for horses, cattle and swine; from 50 to 75 cubic feet for sheep; for

fowls from 15 to 40 cubic feet may be allowed per head in accordance with the size of the birds.

Depending on the cooling power of the air and the kind of animals occupying the stable, a change of from three to nine times per hour appears to be feasible without exposing the inmates to harmful drafts.

Air Movements in Ventilation.—The natural forces which cause the air to move in and out of stables are the wind, the differences of inside and outside temperatures, and the differences of atmospheric humidity inside and outside. Attempts have been made to define by mathematical computation the action of the forces mentioned, but in actual ventilation practice the movements of air are to such an extent modified by friction and other forms of resistance that all formulas can only be credited with a relative value and that after all much remains a matter of conjecture.

As already stated, ventilation problems depending for their solution on the action of natural forces cannot be solved by mathematical methods only.

The Wind.—The passing wind creating differences in pressure inside and outside the stable operates by direct impact and by suctional force. The direct impact asserts itself when a building obstructs the wind's passage and thus a pressure is exerted on the exposed surfaces by which the air is forced into such openings as may be present. This results in increased pressure within. On the leeward side of the building, a negative pressure or suction effect is created through the friction between the rapidly moving body of air and that which is more quiescent. The movement of air out of a ventilating chimney comes about in the same manner.

By the simultaneous operation of impact and aspiration a certain volume of air passes through the space within a building, provided, of course, that there are openings by which it can enter and leave. The rate of air exchange which thus comes about is principally determined by the velocity of the wind, and the relative influence of the latter is shown by the computed air volumes submitted by King as a result of his calculations. They are as shown in table on p. 77.

King, however, estimates that half of the theoretic efficiency may be lost in overcoming resistance, and that the impact value of a 4-mile wind is equivalent to the aspiration value of a 6-mile wind; and, if these factors are additive, that the resulting air movement would be sufficient to meet the needs of more than eight cows (30,000 cubic feet per hour).

Computed Theoretical Flow of Air through a Flue 1 Square Foot in Cross-Section and 40 Feet Long, Due to the Direct Impact and Suction Effect on the Wind at Different Velocities

Velocity of wind, miles per hour	Direct impact. Flow per hour, cubic feet	Suctional effect. Flow per hour, cubic feet
3	21.603	15.817
6	43.205	31.634
9	64 808	47.415
12	86.411	63.268
15	108.014	79.085

Difference of temperature operates as a force in the movement of air, especially when an outlet is provided which makes a vertical flow possible. The force depends on the reduced weight of heated air.

Air warmed or cooled changes its volume $\frac{1}{491}$ for every degree Fahrenheit, so that, in a space of 491 cubic feet, 1 cubic foot will be forced out for every degree Fahrenheit above the outside temperature. Expressed gravimetrically, each degree of temperature increase within will tend to force out of the space 0.08 pound of air, and the difference in pressure will cause an equal weight of outside air to take its place.

Computed Theoretical Flow of Air through Straight Ventilating Flues 1 Square Foot in Cross-Section of Different Lengths and under Eight Temperature Differences. The Observed Flow sare Likely to Be Near 50 Per Cent below These Values

Difference in temperature, °F.	Height of ventilating flue, feet				
	20	30	40	50	60
1	5.828	7.138	8.242	9 215	10.095
10	18.409	22.572	26.064	29.114	31.922
20	26.064	31.775	36.680	41.211	45.114
30	31.922	39.096	45.144	50.472	55 291
40	36.902	45.144	52.128	58.214	63.843
50	41.211	50.472	58.214	65.159	71.378
60	45.144	55.291	63.843	71.378	78.192
70	48.761	59.920	68.958	77.098	84.457

According to King, the draft-producing effects of temperature differences are also influenced by the height of the outtake flue. His computations on the action of temperature differences and height of flue are shown in the preceding tables.

Although theoretic estimates cannot serve as a base for actual ventilation practices, they tend to show the relative value of the factors which are operative in bringing about air movement.

Differences in Humidity.—The weight of air decreases as its humidity becomes greater; and, like the effect of a higher temperature of the inside air, moisture is also apt to increase air movement. It supplements the motive power of heated air; the nearer to saturation the humidity of heated air is, the greater will be its influence. However, the influence of humidity is always considerably less than that of the differences in the temperatures of the inside and outside air and must be regarded as secondary in importance. As humidity and temperature are the principal factors which call for an active air movement, their combined accelerating effect in the presence of adequate provision for air inlets and outlets may be considered as automatically corrective. In the event of the wind action dwindling to zero, they must even be depended on to cause the flow of air needed to do away with the most objectionable features of vitiation.

Air Currents within Ventilated Spaces.—The air movements brought about by the air-moving forces mentioned should be so directed that there is ample circulation throughout the entire space. The even distribution of the moving air not only tends to reduce the occurrence of undesirable drafts, but it also is directly instrumental in the constant removal of the more humid air layers in contact with the body surface of the animals and in the prompt elimination of excessive body heat.

Air currents created in space having a depressing, foul atmosphere have been found to overcome the ill effects of the latter to a notable extent.

The directing of air currents toward the heads of animals occupying the stable, which was often regarded as advisable when the value of pure air was still considered to be entirely due to its effect on the respiratory function, can no longer be regarded as essential in the light of the present knowledge of the subject.

The quintessence of ventilation is the maintenance of a constant and gentle movement of air throughout the entire space inhabited by animals. Even if the exchange of air may be temporarily below that required for optimum temperature and humidity conditions, a

certain degree of comfort will remain attainable as long as there is air movement at all. The compensatory functions which govern the heat economy of the animal body will usually be sufficient to meet contingencies of this nature, which are always apt to arise, no matter how much provision is made for the free play of natural aeromotive forces.

The Control of Air Exchange.—Under the operation of the unstable factors which determine the flow of air, it is not readily possible to maintain a constant optimum condition of the stable air by simple means of control. Nor is it practicable in the ordinary management of stables to operate the means of ventilation in a regularly adequate manner. Even when suitable provisions for ventilation are present, their supervision is commonly difficult and therefore neglected.

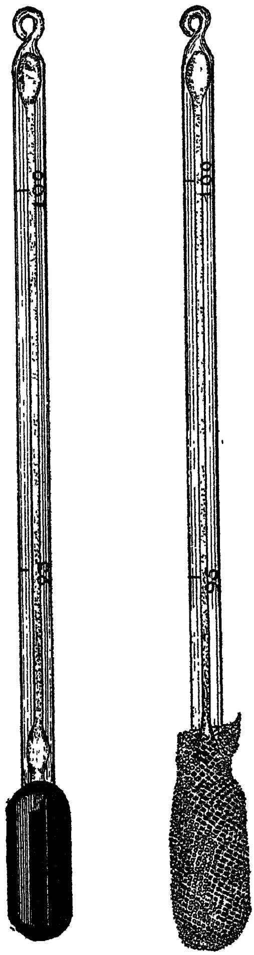

FIG. 2.—Kata-thermometer.

The carbon dioxide content of the stable air, though negligible *per se* from a sanitary point of view, may, however, serve as a criterion of ventilation efficiency. The value of its determination is, however, entirely restricted to investigational studies and cannot readily be applied in the routine supervision of stable ventilation.

A more simple means of control is possible by the use of the thermometer, by which an approximate determination of the purity of the stable air is possible. Having in mind the relative temperature prevailing inside and outside under an established rate of air exchange, it becomes possible to form at least a rough estimate of ventilation performance. Although thermometer readings will not permit a high degree of accuracy in this respect, they have the advantage of such a degree of simplicity that they may be useful in ordinary stable supervision.

Less simple, but more exact in the control of ventilation conditions, is the use of the Kata-thermometer (Fig. 2) invented by Dr.

Leonard Hill. By means of this instrument the cooling rate of the air can be measured when its temperature approximates that of the body. This instrument has been extensively used in ventilation studies pertaining to human habitations, and it seems to be entirely feasible that its use may also supply a relatively simple means of accurately measuring the air qualities which are most potent in their relation to animal comfort and well-being. Unfortunately no data based on Kata-thermometry in stables are yet available, but the results elsewhere obtained are so full of promise for the control of stable ventilation that it is worthy of consideration.

The Kata-thermometer is an alcohol thermometer with a cylindrical bulb about 4 cm. in length, about 2 cm. in diameter, and having a stem of 20 cm. on which temperatures of 95° F. and 100° F. are indicated. The upper part of the stem is provided with a safety reservoir which prevents breakage in the event of over-heating, and which, at the same time, permits the instrument to be heated well above the higher observation point in order to allow time for it to be placed in a suitable situation and to settle down to a regular rate of cooling.

Dry and wet readings are taken. For the purpose of the latter, the bulb is covered with a finger stall of a "lisle thread" glove.

Each Kata-thermometer is calibrated so that the readings can be converted into milli-calories per square centimeter per second. This can be accomplished by a converting number, called the Kata factor, inscribed on the stem of each instrument.

The Kata thermometer makes it possible to measure the cooling power of the air, if the latter does not exceed 90° F. in temperature, or its warming power, when the atmospheric temperature is well above 100° F. The cooling power by radiation and convection is measured by the dry Kata; the wet Kata gives the cooling power by radiation, convection and evaporation. The difference between the two expresses the cooling power by evaporation alone.

In order to obtain the dry Kata the bulb is heated in water of about 175° F. until the fluid rises into the upper bulb and the column is freed of air spaces. When this has come about, the bulb must be promptly removed from the hot water, so as to prevent the bursting of the instrument by further expansion. In order to get the glass into equilibrium, alternate heating and cooling for a few times is desirable if done with care. This done, the instrument is suspended in its proper position after the drying of the bulb. By means of a stopwatch or the second dial of an ordinary watch the time, in sec-

onds, required for the descent of the column from 100° to 95° F. is observed and recorded. Five successive readings are made, and the average of these calculated.

For the wet readings, the bulb is warmed with the finger stall in place. After an alternate cooling and heating a number of times the excess of water is removed from the covering, the instrument suspended, and five successive readings made and averaged in the manner already indicated.

The factor inscribed on each instrument is divided by the average cooling time, the result giving the cooling power of the air in millicalories per $cm.^2$ per second.

According to Hill, the dry Kata cooling power in rooms occupied by sedentary workers should not be below 6 and the wet Kata cooling power not below 18 for the maintenance of comfortable air conditions.

Kata thermometry has not yet found application in the control of stable ventilation, but although the Kata readings indicating comfort for man may be different than those required for animals, there can scarcely be doubt that the same principle is applicable to stable conditions.

Practical Considerations.—The ventilation requirements for stables are subject to a not inconsiderable range of variations. In the tropics and in the moderate zone during the warm season, when stables are intended to furnish overhead shelter only, in which the walls are of open construction, or in which open windows permit the free play of air currents, there is usually no need of special provisions for ventilation purposes. The ventilation is more or less automatic and the inside air will not materially differ from that out of doors. In the colder climates and during the period of winter stabling, purposely designed means for air exchange are commonly imperative. Between the two extremes mentioned, the requirements vary in an endless manner.

Practical experience and the empiric knowledge thereby acquired will always retain a considerable degree of importance in the solution of ventilation problems, whereas mathematical consideration with regard to physical laws, although not to be despised, does not permit the establishment of hard and fast rules for guidance. Only in the case of purely mechanical ventilation systems can formulas become useful for the purpose of the designer, and even then their value is not always predominant.

The successful operation of ventilation will always remain dependent on intelligent supervision on account of the inconstancy of

the air-moving forces. For this reason, the capacity of ventilation equipment should be designed for air movements in excess of actual requirements and be provided with the means of adjustment to meet the need of reduction in air exchange. A degree of elasticity in the provisions made is always warranted.

Natural Ventilation.—The air exchange which takes place in stables of open construction may be designated as natural ventilation. In warmer climates and during the summer months of the moderate zones, the open construction may be quite sufficient and without notable disadvantages. In these instances the construction should be of such a nature that there would be only a minimum of impediment to the play of the wind.

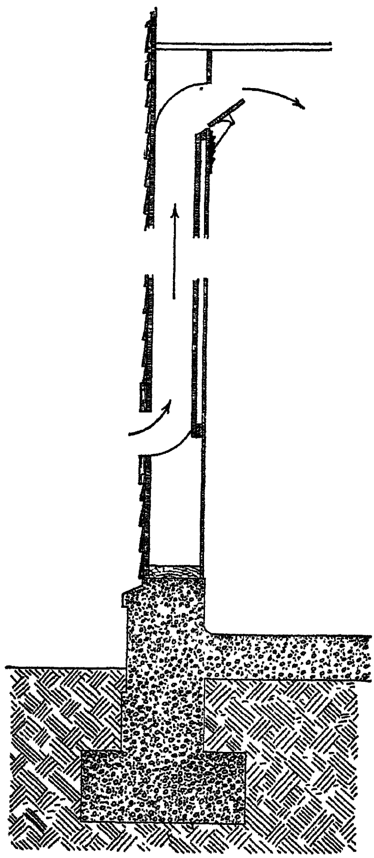

Fig. 3.—Air intake through stable wall.

Not uncommonly, natural ventilation is depended on in regions where the climate or winter weather is more inclement. Under such circumstances, the air exchange takes place through the pores of the building materials and through such seams, joints, and cracks as may exist in walls, roofs, doors and windows. Such means for exchange of air are commonly quite inadequate. The ventilation cannot be regulated, during rain storms the pores in the building material become closed with water, and when the wind dies down, air movement may cease altogether. Moreover, the stable is apt to become drafty and cold when wind velocity increases.

Horizontal Ventilation.—In stables of more substantial construction, special provisions for the intake and outlet of air are necessary if the atmosphere within is to remain of a quality conducive to animal comfort and well-being.

The more simple of these provisions are commonly supplied by special openings in the walls. Such openings may serve as inlets or outlets, their function in this respect depending largely on the direction of the prevailing wind. The openings are usually made in the upper part of the walls. They may consist of straight, direct passageways; or, in order to break the impact of strong winds, they may be so constructed by turning them at square angles that they are given a vertical direction within the substance of the wall (Fig. 3).

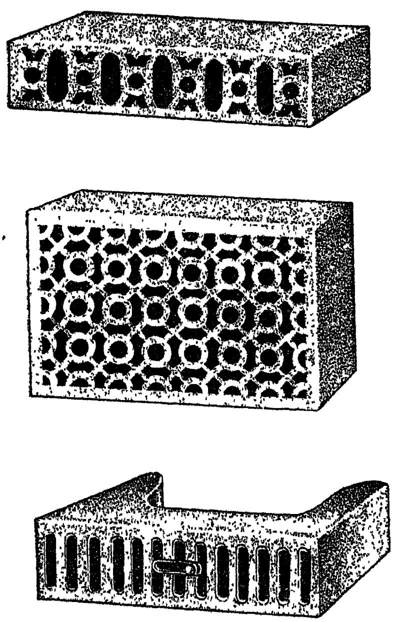

Fig. 4.—Air bricks.

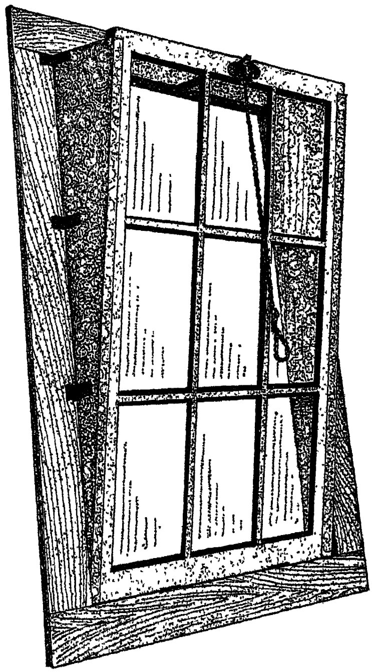

Fig. 5.—Ventilating window.

Such openings usually have a cross-section area of from 15 to 24 square inches, and several of them are, as a rule, provided at intervals of from 6 to 12 feet. By the use of valves a certain degree of regulation of air flow is made possible.

Modifications of this scheme of ventilation are seen in such devices as perforated or air bricks (Fig. 4), Tobin's tubes, Stevens' drawer ventilators, or Sheringham windows (Fig. 5). Of the various types of devices the latter is probably the most useful.

When supplemented by an air outlet through the roof, the hori-

zontal method of ventilation will commonly prove satisfactory in regions with a relatively mild winter climate.

Vertical Ventilation.—A vertical direction of the flow of air or vertical ventilation is more suitable in the more rigorous climates. Not only can drafts be more readily prevented during its operation, but the differences in inside and outside temperatures and humidity can be better utilized as moving forces. Vertical ventilation, in addition, permits a better regulation of air flow inasmuch as the air outlets are less in number, so that by equipping them with regulating valves the means of control become materially simplified.

Although according to some types of design the so-called natural ventilation is depended on for air intake, it is better to combine the vertical means of exit with those for air entry as described under horizontal ventilation.

Combined Ventilation.—The combination of horizontal and vertical ventilation has been especially perfected in this country by King, whose name was given to the method. In sections where a rigorous winter climate demands a substantial stable construction, King's method of ventilation is the most suitable in all cases where mechanical contrivances for air movement cannot find application.

In order to obtain the best results by this plan of ventilation a tight stable construction is quite essential. The method presupposes that the entry and exit of the air will take place through the openings provided for the purpose and that the excess of heat is conveyed outward by means of the outgoing air. The inlets are placed near the ceiling, which should, therefore, be well insulated and as nearly air tight as possible, so that no heat is wasted but may be fully utilized to warm the cold air entering.

As already stated, the outside air enters the stable near the ceiling by means of mutiple openings, properly spaced in the walls. The passage through the wall is not a straight line, and for a distance of a few feet the air is forced to rise in a vertical direction within the wall by causing it to enter at a lower point through an opening in the outside sheeting.

In wooden walls the space between the studdings is commonly utilized for this purpose, a corresponding opening made in the inside sheeting near the ceiling permitting the air to enter into the stable space (Fig. 3). In brick or concrete walls, such air passages may be provided in a similar manner by the use of glazed tiling. The inflow in either case can be regulated by means of sliding valves placed over the inside openings although this is not a strictly essential detail.

The arrangement described is especially desirable in order to prevent the inlets from serving as outlets for the warmed air on the leeward side of the stable.

A greater number of small intake openings placed at intervals of from 8 to 12 feet is to be preferred to a smaller number of large ones. In either case, the total cross-section areas of the inlets should be equal to that of the outtake flues. These flues should be as few in number and as large as practical. They should rise from near

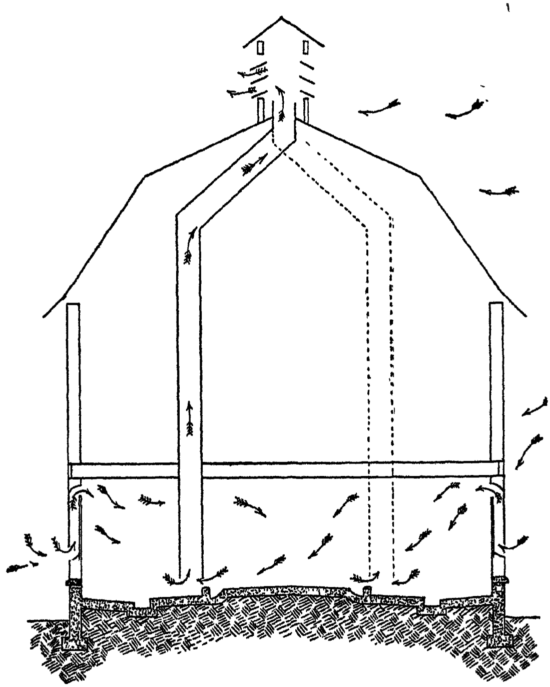

FIG. 6.—Combined ventilation or King's method.

the stable floor to well above the highest point of the roof, so that wind and temperature differences may exert a maximum suction force. They should be of equal caliber throughout, and their cross-section area should be based upon maximum requirements. Either of galvanized iron and cylindrical in form, or of wood and square in cross-section, they should be smooth within and as free from angles as building details permit. The portion of the flue situated outside (above) the warm stable space should be properly insulated in order

to prevent the cooling of the moving warm air. This is particularly required in the case of metal flues.

The outgoing air enters the outtake flue near the stable floor, and the opening provided for the purpose should be guarded by a regulating valve so as to permit the checking of the air flow in the event of excessively high wind velocity or in the case that the inhabitants of the stable should become reduced in numbers.

The external opening of the outtake flue should be protected by some covering device in order to prevent the entrance of rain and snow. The cover should be so placed and so constructed that no interference with the aspirating effect of the wind comes about. Complicated cowls and louvres are not essential and frequently obstruct free air movement.

In the operation of King's method of combined ventilation the air enters the stable at several points near the ceiling, becomes mixed with the warm air collecting at this level and is again gradually evacuated from below. A gentle and constant movement of the stable air is thus maintained.

King estimates that outtakes and inlets for horses and cattle should provide not less than 30 square inches cross-section area per head if the outtake flue has a height of 30 feet. With a height of 20 feet as much as 36 square inches would be required. With an outtake flue 20 feet in height, 22 square inches per head should be provided for swine and 15 square inches for sheep. With a height of 15 feet, the required cross-section areas should not be less than 26 and 17 square inches, respectively. In poultry houses with outtake flues 16 feet above the floor, 4 square inches per fowl or 200 square inches for 50 birds would be required.

It seems quite probable that the above specifications are in excess of actual requirements and even that this excess may result in drafts or chilliness under the operation of certain wind velocities during very cold periods. When, however, adequate provision is made for the control of the outward flow by means of regulating valves, they can be safely accepted as a basis for ventilation plans.

Mechanical Ventilation.—The imperfections of all ventilating schemes depending on natural forces, the development of the electric motor and the readiness with which electric current can often be secured, have combined to introduce forced draft as a means of bringing about the needed air exchange in inhabited closed spaces.

For many years mechanical ventilation has been in use in public buildings or in other large units devoted to a great variety of pur-

poses. On the whole, this type of ventilation has proved to be dependable, readily controlled and economical. Here and there the method has found application in the larger dairy stables, and there is evidence indicating that mechanical ventilation will in time come to play an important part in the ventilation of stables, wherever electric power can be purchased at a reasonable rate.

A rotary fan placed upon the shaft of an air-cooled electric motor or a centrifugal blower furnishes the propelling force by which the air is moved. The fan or blower is placed within a horizontal flue connected in a suitable manner with the outtake flues of the stable, which are arranged in a similar manner as specified for the combined ventilation method. It is feasible so to arrange the equipment for

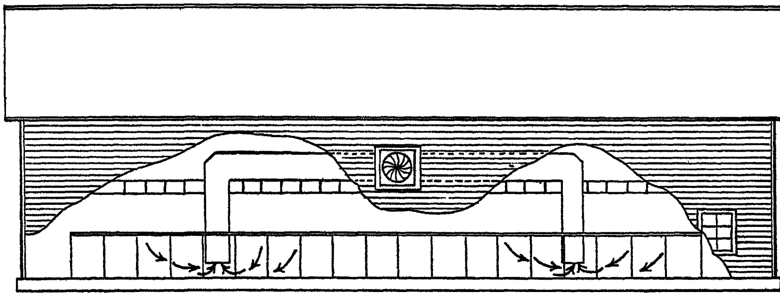

FIG. 7.—Mechanical ventilation. (After Patty.)

the outward flow of the air that either natural or forced draft can be used by means of the same installation.

The amount of air exhausted at the different speeds of the motor can be calculated with a considerable degree of accuracy. It is the one type of ventilation which can be safely based upon mathematical considerations.

Observations made by Kelly and by Patty indicate that apparently satisfactory results were obtained in a stable of substantial construction, occupied by 50 head of cattle, by means of a 24-inch fan operated by a ¼-horsepower motor, air being moved out of the stable at the rate of 3600 cubic feet per hour per head. The amount of current consumed was 1.64 kilowatt hours for a continuous 10-hour run.

In the stable studied by the authors mentioned, the air was changed every 13 minutes. No special air inlets were provided, the suction effect being apparently sufficient to cause the outside air to force its way around windows and doors.

It seems reasonable to suppose that the presence of multiple, small valve-controlled inlets may on occasions prove to be of advantage.

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CHAPTER V

WATER

Physiologic Considerations.—All life is built around water, and water constitutes its most essential requirement. The greater part of the body weight of the domestic animals is composed of water; without it the chemical and physical processes which are the basis of all vital functions would be impossible.

Not only is water the chief component part of tissues and organs, but as a universal solvent and vehicle for all the substances which play a part in the metabolism, it must move within and pass through the body in a more or less constant stream. The body cells are like aquatic animalcules, which, without water, would cease to function altogether.

Although not a source of energy or body fuel, it must be looked upon as a food, and even more than any other nutrient it must be constantly provided. Indispensable thus to life itself, it likewise plays an important part as the most effective cleansing agent, and as such it becomes a factor which influences the quality of the environment in which animal life must run its course.

A part of the water upon which metabolism is dependent forms an integral part of certain foods, such as green foliage, roots, etc. Another part arises within the body from the oxidation of the hydrogen which enters into the chemical structure of food and tissues. A preponderating portion of the water requirement of the body remains to be supplied as drink. This portion must not only be sufficiently abundant, but it must also be possessed of qualities which exercise a wholesome influence on animal health and well-being. Above all, such qualities must include a more or less definite degree of purity and a complete absence of the pathogenic elements for which it may serve as the vehicle by which they can be transported into the animal body.

Chemical Composition and Physical Properties.—In the pure state, water is composed of oxygen and hydrogen in the proportion of 1 to 2 by volume or 8 to 1 by weight (H_2O). It is colorless in small

quantities and pale blue when viewed in a deep column. It is a clear, transparent, odorless and tasteless fluid, which freezes at 32° F. and boils at 212° F. at sea-level. It has its greatest density at 39.2° F. At this temperature it constitutes the base for the determination of the specific gravity of other substances.

Water has remarkable solvent properties for a great number of substances including many gases, and most of its qualities as it occurs in nature are determined by this characteristic, which is further responsible for the fact that pure water does not exist outside the chemical laboratory.

Sources of Water.—Although any classification of water in accordance with its source is entirely an arbitrary one and although no sharp line of distinction can be drawn between the kinds of water set apart, it is convenient to recognize three distinct groups, depending on their sources, namely: (*a*) precipitation, rain or snow water; (*b*) surface water, including that supplied by the sea, lakes, ponds, rivers and streams; and (*c*) ground water furnished by springs and wells.

In reality, the sources mentioned represent only the more tangible phases of the cycle along which water moves in nature. Water evaporated from the surfaces of sea and land gathers as clouds from which it is precipitated in the form of rain, snow or hail, becoming surface water, part of which penetrates into the soil where it becomes ground water. This in turn reappears on the surface through the agency of springs and wells or is raised by capillary movement within the soil or its vegetation and exposed to evaporation.

Rain Water.—In theory, rain water should be the purest in nature, as it is the direct result of condensation from vapor. This purity, however, is not an absolute one because its very condensation takes place on the dust particles of the atmosphere, which are precipitated with the water; also, the raindrops, during their course through the atmospheric strata, gather more dust and micro-organisms, and act as solvents to various substances and gases present in the air. The air is actually washed during a precipitation.

More or less depending on location, rain water may be found to contain, aside from dust and micro-organisms, particles of coal, and iron, lime salts, traces of sodium chloride, ammonium compounds, nitrites and nitrates, sulphites and sulphates, carbonates, organic nitrogenous compounds, and such gases as oxygen, nitrogen and carbon dioxide, in addition to traces of hydrogen dioxide.

The added impurities are slight, however, and quite negligible from a hygienic point of view. The dried residue amounts to from 20 to

50 mg. per liter, and the amount of gases absorbed, influenced by such factors as temperature and duration of precipitation, averages about from 25 to 32 c.c. per liter. The amount of solid impurities decreases with the continuation of the rainfall.

Snow water contains a greater amount of impurities, and as the snow persists for longer periods the water which it yields upon melting usually contains a considerable amount of dust and other contaminating substances. The low mineral content of precipitation water gives it a flat taste.

The average rainfall for the world is about 33 inches per annum; for the United States, about 30 inches. The extremes range between practically no rain at all in certain desert regions to the almost fabulous annual precipitation of from 50 to 65 feet in Assam.

Although rain water is not commonly a direct source of supply for domestic animals, it constitutes the means by which both surface water and ground water are replenished. A continued drouth quite commonly is followed by the drying of wells, springs and ponds and the subsequent more or less serious damage to animal health and well-being.

Surface Water.—The precipitation water that does not percolate into the soil, or is not returned to the atmosphere through evaporation, flows down the declivities offered by the surface formation, forms rills and water courses, which in meeting one another unite as brooks, streams and rivers, or terminate in surface depressions and there form ponds, lakes or swamps. In its downward flow the precipitation water receives the addition of spring water, tears away soil particles and organic débris, takes up the soluble substances of the soil and the air, and wherever it passes through inhabited regions it receives the discharge of sewers, the drainage of farmsteads and fields, the wastes of vessels and of various industrial establishments, such as tanneries, slaughter-houses, gas works, sugar factories, chemical works, etc.

Depending on the velocity of flow and the nature of the ground with which the water comes in contact, the suspended materials are augmented or diminished by further erosion or sedimentation, as the case may be. Inasmuch as the nature of surface water is largely determined by the character of the catchment areas, its composition is so varied that no statement generally applicable can be made. However, it may be said that the further the water of rivers and streams is removed from its sources the more it loses its carbon dioxide and consequently is poorer in the alkaline earth carbonates. It becomes

softer and its oxygen content increases during its downward course. The character of such water is further influenced by the geologic formation through which it flows: a stream passing through a deep, sandy soil is more apt to be free from organic impurities than one passing through loamy or swampy regions.

All surface waters have one feature in common, namely, a rather constant exposure to contamination of various sorts, among which not a few are of the greatest sanitary importance. For this reason, surface water is always looked upon with suspicion by public-health officials, and when such water is to be used by man, it is not only deemed necessary to guard against contamination, but, if at all possible, purification is undertaken as an additional safeguard.

Obviously, such measures cannot find application in connection with surface waters which are to serve as supply sources for domestic animals. Owing to the fact that animals on the whole are less apt to be injured by the drinking of a water that fails to conform to the standards established to safeguard the public health, many types of surface water can be used without great risk. Danger cannot always be excluded, however, and certain animal diseases may be conveyed by water. In certain specific instances, surface water is always open to objections from a sanitary viewpoint for the reason stated. To the latter type of surface water belong the small accumulations, such as ditches, pools, puddles, wagon ruts, and the like. Commonly found in yards or pastures inhabited by animals, they are always open to fecal contamination and are thus apt to serve as the vehicle for a number of microbic diseases and the eggs and larvae of parasites. Of a similar nature is the water contained in small lakes or ponds which receive the surface drainage of areas inhabited by man and animals.

Subject to the influence of a number of factors, the quality of surface water is always dominated by the character and location of its environment. It may lose many or all of its undesirable features by a process of self-purification, however. Sedimentation, dilution, oxidation as well as biologic influences may materially alter its sanitary qualities in a favorable manner.

Sea water is always unfit to be used as drinking water. Its high saline contents has frequently been responsible for serious gastrointestinal disturbances in animals which, through excessive thirst, were forced to partake of it. Sea water contains per liter approximately 35 grams of salt of which 27 grams are sodium chloride, the remainder being composed of the chlorides of potassium and mag-

nesium, the sulphates and carbonates of calcium and magnesium as well as certain bromides and iodides.

A similar unfitness for drinking purposes comes about in surface waters in small bodies, when their original harmless saline content becomes concentrated through evaporation during prolonged periods of drouth.

Ground Water.—That portion of the precipitation water which enters the soil and which is not returned to the surface by soil capillarity or root action ultimately constitutes a collection of water known as the ground water. It has been estimated that approximately one-third of the water falling upon the land enters into the soil as far as the latter is permeable. As it penetrates, the water fills the pore spaces and pursues its downward course under the influence of gravity until further progress is arrested by an impermeable soil stratum. Above such a layer, commonly formed by a heavy clay or by intact rock, the water more or less completely fills the available pore space up to a certain height. This constitutes what is known as the ground-water zone.

As the stratification of the earth's crust is but rarely a horizontal one, the water stopped in its perpendicular downward course, always obeying the law of gravity, is forced to follow the declivities of the impermeable layer which gives it support. Thus comes about a definite movement of the ground water of which the velocity is determined by the size of the pore spaces of the open soil layer as well as by the slope of the closed layer over which it flows. The movement, however, is always a slow one, ranging from 10 to 200 cm. per hour.

As a sheet of ground water gradually proceeds along the slope of its impermeable base to greater depths it may reach regions where it comes to be situated below one or more other impermeable strata. For this reason a single boring may pass through separate water-bearing layers having no connection with one another and yielding waters of different composition.

When the sheet of ground water does not occupy the entire thickness of the water-bearing stratum it is known as a free body of ground water; it is designated as captive or artesian when under pressure it occupies the entire space available within the layers. In the latter case it will freely issue from the surface when an outlet, natural or artificial, is provided.

The level of a free sheet of ground water changes rather constantly, its surface rising and falling under the influence of precipitation, season and possibly also of changes in barometric pressure.

The surface of the groundwater sheet, as a rule, does not conform to that of the land, but is parallel to that of the impermeable stratum which supports it.

The character of the ground water is determined by the nature of the soil layers through which it passes. With the penetration of the precipitation water into the soil a series of changes and processes are inaugurated which, dependent on the nature of the ground and the duration of the percolation period, are responsible for the ultimate character of the water.

As the water passes through the impure superficial soil layers, it takes up a part of the detritus and micro-organisms present, which, in a dissolved or suspended state, contribute to the water the qualities peculiar to the surface water in general. During its downward course, the suspended impurities are removed by filtration, and those in solution are for a large part given off to the soil. It becomes thus increasingly unfit to sustain an abundant bacterial flora. The further the water travels through the soil, the purer it becomes in regard to organic substances, so that frequently the deeper strata are to be given preference from a hygienic viewpoint.

The deeper waters may, however, have their hygienic fitness seriously impaired by an excess of inorganic salts, which entered either in solution, because the solvent powers for such substances as certain carbonates and silicates may become markedly increased by the quantity of carbon dioxide which the water takes up in the soil, or by the presence within the soil of soluble chlorides, nitrates, sulphates and other substances which tend to affect its quality as drinking water.

Although the deeper ground water is a common and highly desirable source of supply, the possibility of its becoming contaminated must not be overlooked. Such a pollution may come about by excessive looseness of texture of the more superficial soil layers through which the water passes or by their saturation with organic wastes. In certain limestone regions, the pollution may be conveyed for long distances through passages and crevices peculiar to this type of geologic formation. No ground water can be regarded as entirely safe from contamination whenever the precipitation water can communicate with it after a previous and adequate exposure to the soil influences already mentioned.

On the other hand, many superficially situated bodies of ground water may be as pure as that which can be procured from deeper strata. This favorable condition is brought about by a fine and homo-

geneous texture of the covering permeable layer of such a thickness as to permit a thorough filtration and other purifying soil action.

Ground water may become available for use through springs and

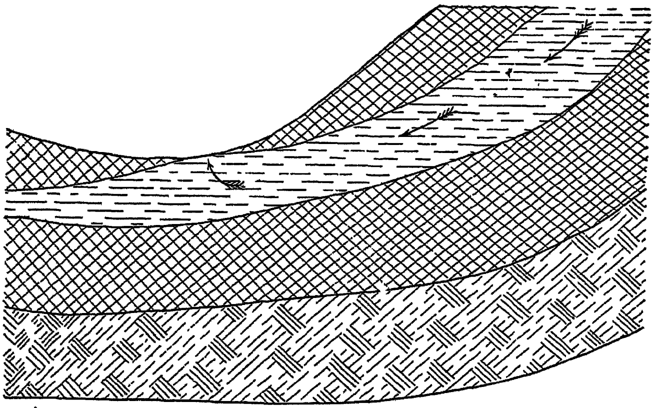

FIG. 8.—Land spring or dip spring.

wells. A spring is any natural outlet of the ground water at the surface; it may come about in various ways. When an impermeable stratum supporting a water-bearing layer becomes exposed at the sur-

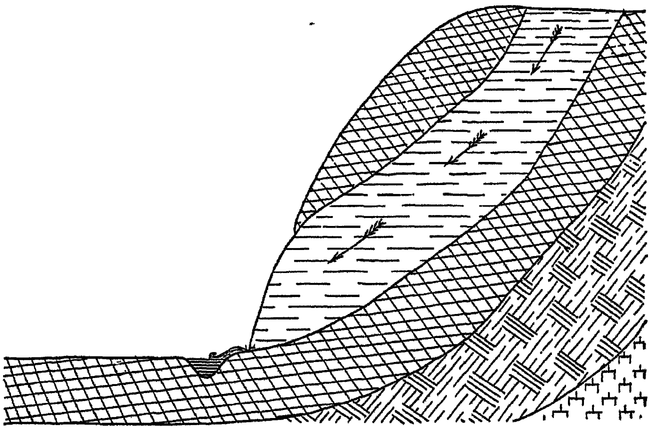

FIG. 9.—Fissure spring.

face through a dip of the land, the water which rests upon it may find an outlet, and a spring is the result. Such a spring is known as a "land spring or dip spring" (Fig. 8). The water issuing from such

a spring may be either mere surface water or ground water which has undergone the entire process of natural purification, depending on the thickness and texture of the covering strata. Such land springs, often becoming dry during periods of drouth and "breaking" again after precipitation, are as a rule not dependable sources of supply. Only when the water issues from deeper strata is the flow a fairly constant one.

A spring may also be formed by a fissure or crevice in an impermeable stratum such as rock. In such a case the spring is known as a "fissure spring" (Fig. 9). The water of such a spring is usually

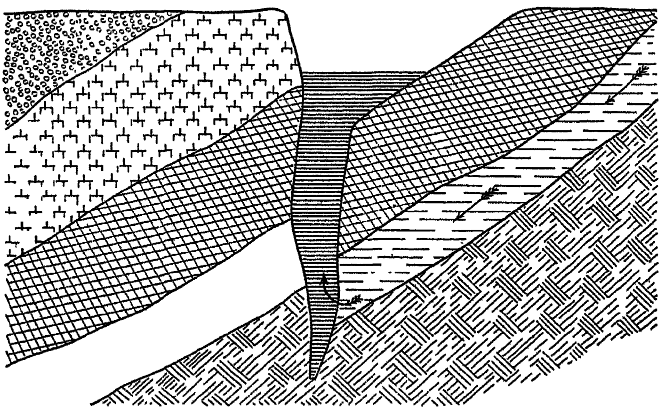

FIG. 10.—Junction spring.

of a deep origin; the flow is commonly a constant one, and its quality is ordinarily one of a desirable degree of purity.

Ground water sometimes finds an outlet by means of a so-called "junction spring" (Fig. 10). Such a spring results from geologic faulting, and the quality of its water may range from that of surface water to that of a most desirable ground water in accordance with the nature and configuration of the land.

Wells are artificial means of gaining access to an available supply of ground water. They consist of either a hole dug or a pipe driven into a water-bearing stratum, which may either be a deposit of sand or gravel, sandstone, rock or limestone formation.

Three distinct types of wells are recognized, namely: shallow, deep and artesian. The term "shallow" as applied to wells is rather misleading because it does not necessarily imply that the well is not

deep. A shallow well is any well which penetrates into a water-bearing layer without first passing through an impermeable stratum.

A deep well, on the other hand, is any well which derives its water from a body of ground water situated below an impervious layer of

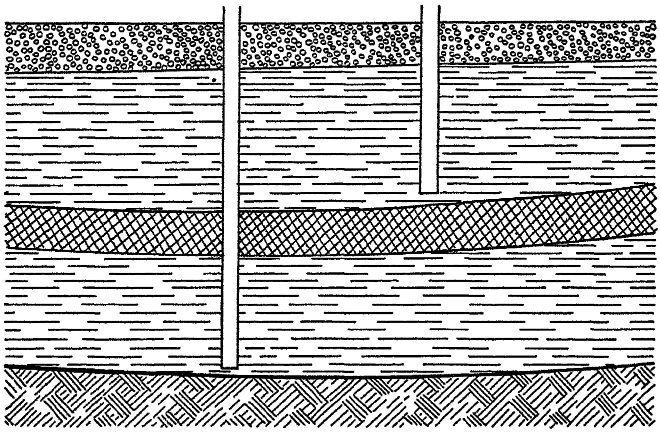

Fig. 11.—Deep and shallow wells.

soil (Fig. 11). Thus a shallow well in one locality may be much deeper than a deep well in some other place.

An artesian or flowing well (Fig. 12) furnishes the artificial outlet for the water of a water-bearing stratum which is subjected to

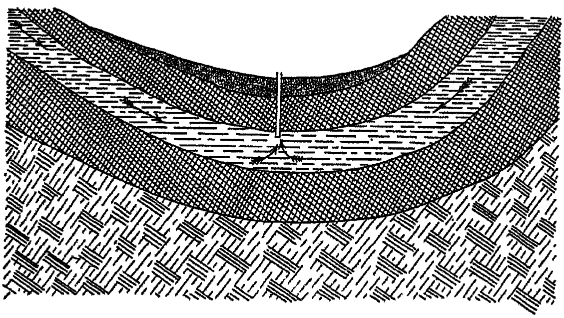

Fig. 12.—Artesian well.

hydrostatic pressure. Such a stratum is situated between two impervious ones and is exposed at the surface at a higher level than that of the locality of the well. The result is that at a lower level the water will flow or spout from the well without the aid of any

special contrivance. Such waters are often obliged to travel within the permeable layer for great distances and they are commonly obtainable only at considerable depths (300 to 3000 feet or more).

Although the water obtained from shallow wells situated in sandy or gravelly formations far enough removed from sources of pollution may be quite fit, hygienically considered, that procured from deep or artesian wells is, as a rule, preferable, provided it does not contain an excessive amount of mineral impurities. Aside from being often quite hard or saline, it may also contain an objectionable amount of iron.

Wells sunk in sandy or gravelly strata or into sandstone often yield the most abundant and purest waters. Fissured limestone formations may also provide satisfactory supplies, but owing to the fact that they may be open to surface contamination this source cannot always be regarded as entirely safe.

Hygienic Requirements.—It would be entirely impracticable to insist on the high standards established for water to be selected for human consumption, when a water supply exclusively intended for the use of animals is to be chosen. Certain purely esthetic features essential for the former are less important for the latter. Only in those branches of animal industry (dairies, creameries, abattoirs) which have a direct bearing on public health and in which the water offered as drink to animals and that used for cleansing are derived from a common source must all the sanitary requirements, demanded of a safe drinking water for man, be fulfilled.

Nevertheless, it is quite desirable to provide domestic animals, whenever possible, with a drinking water of a faultless character. A water supply for animal use should be abundant, not only to meet the maximum physiologic requirements, but likewise for the maintenance of cleanliness in connection with the animals themselves, the stables and the various utensils used in their management. A drinking water should be free from objectionable taste and odor. The willingness with which animals partake of it is usually a sufficient criterion in this respect. A marked degree of cloudiness and the presence of conspicuous suspended impurities are to be looked upon with suspicion, especially on the ground that a water showing such characters is apt to be open also to more harmful forms of pollution. Most important of all is the requirement that it be free from disease-producing factors and that the location of the source of supply be such that their entering the water can be reasonably excluded.

At no time should a water supply be open to contamination by pathogenic microbes or the eggs or larvae of animal parasites; also

the possibility of the addition of mineral poisons (lead, arsenic) is always to be rigidly excluded.

Water Impurities.—All substances found to occur in water may be included in the general term of "impurities." The name impurity, however, must not always be regarded as synonymous with "undesirable." Both good and bad qualities of water are mostly determined by impurities—the substances found in water which are not water.

Distilled water of almost absolute purity, as a matter of fact, is objected to on account of a flat or otherwise undesirable taste and is reputed to be badly tolerated, although such objection does not appear to rest upon solid ground.

Water impurities occur either in solution or in suspension.

Dissolved Impurities.—These consist of (*a*) gases, (*b*) minerals, (*c*) organic compounds and (*d*) toxic substances.

The gases found in water are oxygen, carbon dioxide and nitrogen. As far as their direct action in the animal body is concerned, they are probably inert, although in fish culture the amount of oxygen contained in the water has a definite importance. Their presence may render a water more palatable. In a more indirect manner the oxygen content of a water may be looked upon as a gauge of its hygienic value inasmuch as it serves to indicate the degree of purity so far as organic contaminations are concerned. Organic substances tend to combine with the free oxygen and thus are reduced in amount. Nitrogen contained in water is without action or importance. Carbon dioxide derived from the atmosphere and from the oxidation of organic matter increases the solvent powers of a water for some of the mineral constituents of the soil.

The mineral substances found in water include a far greater assortment. Widely distributed are the chlorides, carbonates, sulphates, silicates and the phosphates of calcium, magnesium, sodium, potassium, ammonium, aluminum, iron, and other elements.

It is not possible to determine definitely how much mineral matter a water may contain in order to be regarded as a satisfactory drinking water. A knowledge of the mineral content, may, however, be extremely useful when it becomes necessary to establish the presence or absence of contaminating influences. Sudden changes in quality or quantity of the normal ingredients of a given water always indicate a foreign admixture which may be of considerable sanitary importance.

Most waters contain chlorine in the form of the chlorides of sodium, calcium and magnesium, and the chlorine titer is ordinarily a more or less stable one. A marked and sudden increase in the chlorine

titer indicates that the chlorides of another source have been added, and this may point directly to the possibility of sewage pollution.

The occurrence of phosphoric acid in appreciable amounts is nearly always an indication of a more or less serious contamination by sewage or stable wastes inasmuch as its principal source is urine, always included in such discharges.

Nitrogen in combination to form ammonia, nitrites and nitrates is not uncommonly encountered in certain waters and must always be regarded as evidence of organic contamination. Those substances are the final products of the mineralization of proteid matter and thus when found in water speak for a more or less remote pollution. Ammonia and nitrites indicate a contamination in process of reduction, and nitrates indicate that this process has been completed. Analysis reports refer to ammonia as free tangible ammonia and as albuminoid ammonia. The latter forms in the analytic process by the breaking down of the more complex nitrogenous compounds.

A number of the mineral constituents of water, among which calcium and magnesium salts are prominent, form insoluble compounds with soap and thus endow the water with the quality commonly designated as hardness. Hardness may either be permanent or temporary. In the latter case, the hardness, at least in part, is removed by boiling. Temporary hardness is acquired when a water charged with carbon dioxide passes through a stratum of limestone. The carbon dioxide in the presence of water exercises a marked solvent action, the calcium being dissolved in the form of bicarbonate in this manner:

$$CaCO_3 + H_2O + CO_2 = Ca(HCO_3)_2$$

The $Ca(HCO_3)_2$ is soluble, but when under the influence of heat its carbon dioxide is driven off, the resulting carbonate is practically all precipitated. A similar reaction occurs with the carbonate of magnesium.

Permanent hardness is due to the presence of the chlorides, sulphates, carbonates and other compounds of calcium, magnesium, iron and other metals which form insoluble combinations with the soaps used for domestic purposes.

Although water hardness is more objectionable from an economic or culinary point of view than from a sanitary one, waters of pronounced hardness should be avoided if at all possible. The theory has been advanced that a drinking water rich in calcium salts may be

an important contributory factor in the etiology of urinary lithiasis, but this belief is by no means based on proved facts.

Iron is a mineral impurity present in many waters. It occurs as ferric as well as ferrous salts. Its most common source is the pyrite or mineral sulphide which oxidized to sulphate is readily dissolved. This may be further changed to carbonate or may appear as the colloidal hydroxide. These substances are apt to confer to the water a brownish color and to become deposited as a sediment of the same color upon standing. Organic iron compounds may also occur in water. Water containing iron has been looked upon as a cause of constipation, but it is doubtful that this impurity has really a sanitary significance. It may, however, give a water a disagreeable, inky taste and it favors the development of such micro-organisms as *Crenothrix.*

Compounds of silicon and aluminum found in water are without hygienic importance, and the same can be said of the more rare salts of iodine, bromine and fluorine, of which traces have been found to occur.

Dissolved impurities of an organic nature occur in practically all waters, the purest not excepted. Derived from the decomposition of vegetable matter and in the form of humus substances, they contribute no objectionable qualities. Of more serious importance are they when they come about through the pollution with body wastes, like urine, feces, or with factory discharges. They are too numerous to be mentioned in detail, but it is certain that a high titer of dissolved organic material is sufficient reason to regard the water concerned as polluted. Their presence is always ground for the suspicion that the water supply is open also to pollution by pathogenic factors.

Among the dissolved impurities of a toxic nature, lead, zinc and arsenic must be mentioned. Lead in toxic quantities may be derived from lead containers and piping inasmuch as this metal is apt to be attacked by certain types of water, among which the softer waters containing carbon dioxide occupy a prominent place. Lead poisoning of animals has also been observed after their drinking of water in the vicinity of lead mines and of that carried by streams flowing through lead deposits. Water contamination by the discharge from paint factories (lead white) may also bring about lead poisoning.

More uncommon is the poisoning of animals by water containing zinc. It has been found to occur in the vicinity of zinc mines and through the agency of zinc-carrying streams.

Water may likewise become toxic on account of a certain amount

of arsenic supplied by industrial wastes (dye factories) and through seepage or leaks from adjacent cattle or sheep dips.

Suspended Impurities.—The suspended impurities which may be present in water may be either inorganic or organic in nature. They determine the various degrees of turbidity by which waters may be characterized.

Inorganic suspended matter is commonly composed of clay particles, which owing to their extremely minute dimensions (less than one-tenth of a micron) may remain in suspension for considerable periods. Turbidity on account of clay particles is common in river waters and is occasionally encountered in ground water. Only in the latter case should turbidity be looked upon with suspicion as a possible consequence of surface contamination.

Sand particles remain in suspension for a short time and are, as a rule, of no sanitary importance. Only when they are kept in a more or less constant suspension by agitation may they become noxious by being swallowed in large amounts. Horses wading in shallow ponds or streams with a sandy bottom and drinking the water in considerable quantity may take in enough sand to cause intestinal irritation (sand colic).

Organic suspended matter is quite common in water, especially that supplied from ponds, rivers and open containers. It consists either of the fragments of plants, such as cells, spirals, hairs, fibers, partially decomposed leaves and straw, or such débris of animal origin as hairs, feathers, parts of insects and the scales of the wings of moths and butterflies or of living organisms of a vegetable or animal nature. Impurities of this sort are as a rule harmless *per se,* but their presence generally indicates that the water concerned is also open to pollution of a more serious nature.

In this connection the possibility that living pathogenic factors may form a part of the suspended organic impurities of water must be given consideration. Gaining access to it through pollution with body wastes and through carcasses disposed of in water courses, they constitute the principal danger attached to surface contamination. Practically all microbic and parasitic diseases of which the etiologic factors are capable of infecting through the alimentary canal are apt to be water-borne. To those diseases a contaminated water may and frequently does serve as a very potent vehicle in dissemination.

Water-borne Diseases.—It does not appear that the livestock sanitarian is apt to be confronted with problems of water-borne disease comparable with those presented by cholera asiatica, typhoid fever

and dysentery of man. The fact that animals have been known to drink very badly polluted water, or water contaminated even by sewage, without apparent ill effects is responsible for a rather general belief that the use of such waters is more or less harmless. There may be no proof to the contrary, but neither is there any evidence to show that under all circumstances sewage-polluted water is entirely safe. It is known, however, that pure unpolluted water cannot cause harm and that in the selection of a water supply wholesome drinking water must be given preference.

The quality of sewage pollution as well as the degree of its concentration may be determining factors. However, it seems rather unreasonable to speak of the harmlessness of sewage to animals. Even if this sewage is largely of human origin there is good reason to expect a certain amount of risk, if part of it were of animal origin and issuing from an animal population in density comparable with that of an urban human population. If elements specifically pathogenic to animals are present in the sewage, a water polluted by it would be as hazardous to animals as a typhoid, or cholera-carrying contamination would be to man.

The great difficulty often associated with the experimental demonstration of pathogenic microbes in water is in no small way responsible for the unsatisfactory state of our knowledge of the danger of sewage contamination to animals.

Without being water-borne in the manner of cholera, typhoid fever and dysentery, most animal diseases capable of entrance through the alimentary canal may be conveyed by means of water. A notable example is supplied by the dissemination of anthrax by the pollution of water courses by tanneries, brush factories, woolen mills, etc., using raw materials of animal origin. On the whole, it is very doubtful that the anthrax bacillus multiplies in water, but its spores have been found to retain their viability in water for at least 17 months. By the overflow of such contaminated water courses the disease may be widely scattered over adjoining meadows and pastures.

Fowl cholera also may be conveyed by means of the drinking water, and particularly in connection with outbreaks of this disease among water fowl. Water pollution is regarded as the source of the outbreaks of cholera which periodically bring disaster to the duck growers on the marshes of certain parts of the Netherlands. In a water reservoir constructed by Kitt in which the excrements of a sick goose had been voided, the virus was preserved for several weeks so that newly purchased geese placed in the reservoir promptly sickened,

whereas controls belonging to the same yard and having no access to the water remained healthy.

The public watering-trough has frequently played the part of a proficient distributor of glanders infection, and the drinking water of swine may become the vehicle for swine erysipelas in permanently infected regions or after the pollution of water courses by the rinsing water used during emergency slaughter of affected animals.

In part, at least, water contamination may be responsible for the dissemination of cattle plague, strangles, blackleg, the Borna horse disease, fowl typhoid and other diseases caused by members of the colon-typhoid group; unclean, muddy water is mentioned as a cause of gastro-intestinal catarrh and colic in horses. Tetanus bacilli were found in the silt of lake Geneva and the Dead Sea, although it was not shown that water was a factor in the etiology of that disease.

Stagnant waters to which animals have access may play a part in the distribution of coccidiosis of poultry, sheep, goats and cattle. The eggs and larvae of a great number of parasitic nematodes, the eggs of cestodes and the cercaria of trematodes are also transmitted to their temporary or permanent hosts by the same means.

The infection possibilities associated with polluted water are always to be regarded as reason sufficient for the exclusion of contaminating factors from the drinking water to be supplied to domestic animals, and in addition, more subtle and as yet unknown influences connected with a pure water may, as in man, be concerned in the hygiene of animals.

It was noted that after the elimination or material reduction of the morbidity of typhoid fever through improvement of the public water supply of a number of cities, there was a corresponding decrease in the death-rate of other diseases not particularly connected with the water supply. This feature is known as the Mills-Reincke phenomenon, upon which Hazen based a theorem that when one death from typhoid fever has been avoided by the use of a better water, a certain number of deaths, probably two or three, from other causes have also been avoided. The same underlying factors may or may not operate similarly in other species, but the Mills-Reincke phenomenon certainly points to the great sanitary importance of pure water in addition to its more definitely known hygienic influence.

Water Examination.—In the maintenance of the public health as well as in the tracing of disease outbreaks to their causes, the examination of water and the local conditions under which it is obtained or collected play parts of a not inconsiderable importance.

Water examination occupies a less prominent part in the hygiene of animals, for they are not constantly menaced by water-borne diseases in the manner that man is; furthermore, the cost of supervision and analyses must be given consideration inasmuch as, in general, livestock sanitary efforts have only a purely economic purpose. For obvious reasons, however, inquiry into the nature of a supply of drinking water has its place in animal sanitation, not only as a means of selecting the best water obtainable, but also when, in the face of existing microbic or parasitic diseases, the character of the water may be challenged or when toxic impurities are suspected to be present.

In judging the hygienic value of a water supply, the examination may include: First, local inspection; second, chemical analysis; third, microscopic examination; and fourth, bacteriologic analysis.

Local inspection is of the greatest practical importance and usually exceeds in value the purely analytical methods of water examination which must be carried out more or less constantly and repeatedly if they are to furnish the basis for practical conclusions. The local inspection determines certain physical qualities, such as turbidity, clearness, odor, taste and color. It serves especially to reveal the possibility for pollution and for the introduction of disease-producing factors.

When surface waters are depended on as a source of supply the drainage areas which contribute to them should be examined for pollution by animal excreta, stable wastes and the presence of carcasses. With the smaller bodies of standing water, it is of value to observe if livestock have access to them or to their immediate surroundings. With springs, it is well to ascertain the position of the water-bearing strata in relation to the surface, so that possible contaminations originating on the surface may be recognized. This is especially important when the spring is situated in limestone formations, for these not uncommonly show cracks and crevices which furnish an avenue for the entrance of polluted surface waters and the drains of stables, cesspools and the like.

In the detection of possible sources of pollution in connection with springs and wells, substances which have a characteristic odor, taste or color or which can be readily recognized by analytic methods may be employed. Such substances are fluorescin, coal oil, and saprol, and the voluminous cultures of yeast or the *Bacillus prodigiosus* may be used for the same purpose.

The local inspection of wells includes the same details as that of springs, but further attention must be paid to their construction.

Defects in the well casing, its cover, in fact all avenues which may open the way to surface contamination, must be carefully searched for. Wells having a stone or brick curbing and of sufficient width should be opened and examined by artificial light, if necessary. The presence of white or dark streaks on the walls or of leaves, insects, etc., on the surface of the water indicates the possibility of surface pollution. The location of the well must also be observed. Wells within stables and those situated in low places subject to overflow must always be regarded with a certain degree of suspicion.

The chemical analysis of water, aside from the cases in which the presence of toxic impurities is suspected, has not the value with which it is credited in the popular mind. Only when the results of an analysis can be compared with those obtained on a number of previous occasions, can they be accepted as evidence of pollution or of its absence.

Increase in the amounts of ammonia, nitrites, nitrates, phosphates, sulphates and chlorine may point to contamination and such waters may be regarded as unsafe; the same opinion is warranted in regard to those showing a conspicuous amount of organic substances.

The microscopic examination of water sediments sheds light on the presence and nature of an almost unlimited number of species of micro-organisms of vegetable and animal origin. Aside from their ability to contribute to the water objectionable odors or tastes, they have no direct sanitary significance. They are not pathogenic although their presence in conspicuous amount may signify pollution. On the other hand, the microscopic examination may reveal elements indicating that a more dangerous contamination has taken place. Such elements are the eggs and larvae of helminths or other evidences of fecal matter.

The bacteriologic examination but rarely permits very precise conclusions in regard to the sanitary value of a water. A count of bacteria may show the degree of contamination which has taken place, but the direct demonstration of pathogenic elements succeeds only in an extremely small proportion of the analyses made. The presence of *Bacillus coli communis*, in a more indirect manner, may often be considered as evidence of pollution of a fecal nature.

Although the local inspection, carefully and thoroughly made, will usually enable the livestock sanitarian to conclude correctly in regard to the sanitary qualities of a water supply, occasions may arise when chemical, microscopical or bacteriological analyses are apt to give material assistance in the solution of water problems. For directions of

analyses, the "Standard Methods for the Examination of Water and Sewage of the American Public Health Association," fifth edition, is recommended for guidance.

As such analyses are more commonly undertaken by specially trained water analysts working in established laboratories than by livestock sanitary officers, attention should be given to the selection and preparation of the water samples to be examined. The minimum amount of water to serve as a sample is 2 liters. It should be collected and forwarded in glass-stoppered bottles after they have been carefully cleansed, dried and sterilized. The stoppers and necks of the bottles are to be protected by means of cloth or thick paper caps securely tied on. The use of jugs or metal containers is objectionable.

Care should be taken that a truly representative sample be secured, and when water occurring in volumes of considerable size is to be analyzed it is always preferable to prepare several samples taken at different places and at different depths. When the water is taken from a well by means of a pump, the pump should be previously operated for a few minutes, and when the sample is to be obtained from a tap the water should be allowed to run freely for the same length of time, so that substances present in pumps or pipes will not vitiate the sample.

If possible, water samples should be packed in ice, and the shorter the time elapsing between collection and analysis the more reliable will be the results. The time limits for transit have been arbitrarily fixed at 72 hours for unpolluted water, at 48 hours for fairly pure water and at 12 hours for polluted water.

The Hygiene of Supply Sources.—In the hygiene of the various sources from which the drinking water for animals must be obtained the prevention of contamination with disease-producing or toxic factors is practically the only object to which attention must and can be given. Only when there is a choice between different sources of supply such qualities as taste, odor, clearness and temperature can be considered, and then preference must be given to those waters meeting the esthetic standards set for a good drinking water for man, provided that the chances for pollution are equal.

Rain water is not commonly used for the watering of animals. Only in regions where the brackishness of surface and ground water renders it unfit for use and where precipitation is adequate can this source of supply be considered. Collected on the roofs of houses, barns and stables, the catchment area is commonly insufficient to serve a large animal population, and the surfaces upon which it is collected

add to the water a considerable amount of impurities, rich in organic matter, subject to decomposition and putrefaction.

These impurities are usually of a harmless character, and even the initial disagreeable odor to which their decomposition is prone to give rise will disappear upon standing, for the process of self-purification brings about a more or less complete mineralization of the organic substances washed down from the roofs. The coarser impurities may for a large part be removed by the use of a simple sand filter (Fig. 13).

Precipitation water is usually collected in underground cisterns which should be protected against surface pollution in the same manner as the shallow, excavated well. Rain water cisterns are best constructed of concrete; metal and wood are less suitable for the purpose. It is advisable to cover the inner surface of the concrete wall and bottom with a coat of asphaltum or coal tar to prevent seepage and the hardening of the water by the solvent action on the calcium constituents of the concrete.

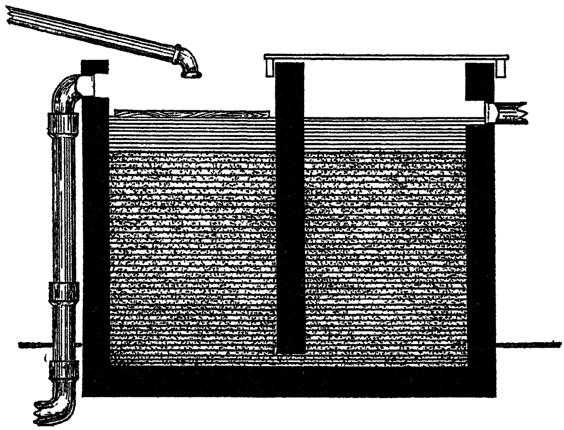

FIG. 13.—A simple sand filter.

Open bodies of water such as lakes, ponds, impounded reservoirs and streams are common sources of supply. Especially the smaller accumulations of standing water, unless situated in sparsely settled regions, must be looked upon with suspicion from a sanitary point of view. Commonly open to fecal contamination, they are apt to be instrumental in the propagation of microbic and parasitic diseases. These diseases may to a considerable extent be prevented by excluding the animals from direct access to the water by fencing, and by pump-

ing the water into the drinking troughs and passing it through a sand filter of suitable construction and capacity. Larger streams are usually safe. Smaller ones may be so likewise, but their freedom of pollution by stable drains, sewers and factory wastes should be previously established by a careful, local inspection.

The most desirable water to be supplied to domestic animals is the ground water obtained from springs and wells, even if the danger of surface pollution must be constantly guarded against. From a hygienic point of view springs must be looked upon as being no better than shallow wells. As such they may be exposed to an occasional influx or a permanent seepage of surface washings from hog lots, stable

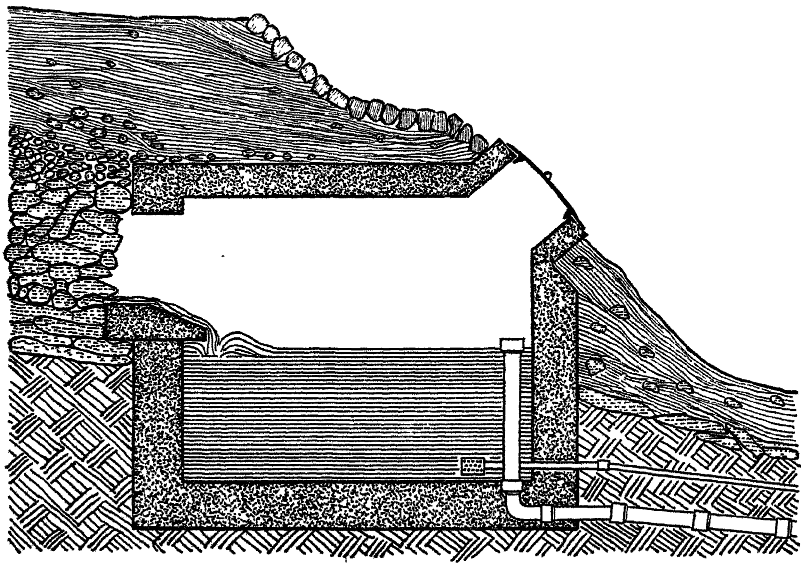

FIG. 14.—Protected spring chamber.

yards, cesspools and stable drains. Thus, in the vicinity of springs, soil contamination must be prevented and animals kept at a distance.

When a spring is to be depended upon for a water supply, there are advantages in having it protected by the construction of a concrete or masonery spring chamber or reservoir (Fig. 14). At the same time provision can be made for the adequate disposal of the overflow, so that no water accumulations can gather in the immediate vicinity of the spring. Surface water washing toward the spring should be conveyed away laterally by means of a ditch dug around both sides of the spring.

If the spring yields abundantly and constantly the capacity of the reservoir may be small, otherwise it should be sufficiently spacious to serve for water storage, so that only a minimum of water would be lost as overflow.

Wells provide the most common means of rendering the ground water available for drinking and other purposes. Of the three types of wells already described, namely the shallow, deep and artesian, the shallow most commonly constitutes somewhat of a sanitary problem. Especially the older type of dug or excavated well is liable to present defects which at times may constitute a menace owing to the various kinds of pollution to which its water may be exposed.

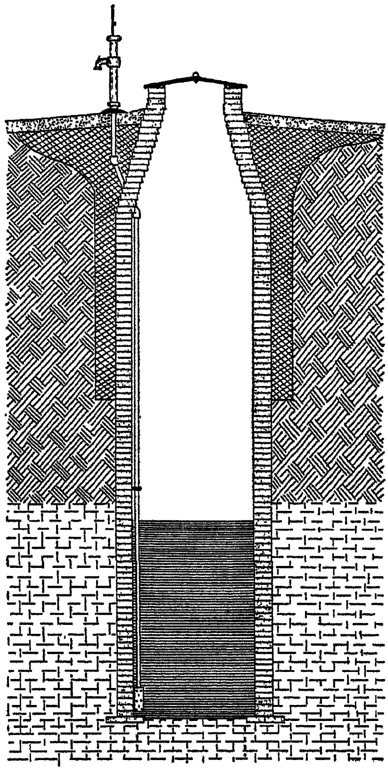

Fig. 15.—Sanitary shallow well.

Position of the well with reference to such sources of contamination as cesspools, open stable or stable yard drains and the like must always be given consideration, and the texture of the surrounding soil is likewise to be taken into account. A loose, sandy or gravelly soil is more apt to permit the passage of formed impurities than a tight, clayey one. The distance between a possible source of pollution and the well is thus an important factor; it is a sound practice to follow the counsel given by Smith that, in choosing a well site, the distance between a possible polluting source and the well should be from 100 to 160 times the depth measured to the surface of the water, and even greater if the lowering of the water level is likely to be considerable.

Even the shallow well should be deep enough to reach into soil layers poor in bacteria and at least one or more yards below the water table at its lowest position.

In the construction of the well curbing, tightness sufficient to com-

pel the water to enter only from below is the principal consideration. Brick, stone or concrete blocks, pointed on the inside or plastered with cement, are to be preferred to wood; the outside should be further protected by a thick layer of puddled clay (Fig. 15). The well curbing should extend from 12 to 18 inches above the grade line, and the surrounding surface should slope away from the well opening in all directions.

The covering of the well should be made water tight. Contrary to the popular opinion that wells require ventilation, well water keeps better in the dark and protected from the outside air. Tightness of construction thus is an imperative feature, for most of the pollution is derived from surface influxes and not from subsoil seepage.

If at all possible, the pump should be placed not above the well, but to one side of it, and all waste water should be suitably conveyed away.

Driven or bored wells are the most satisfactory as they are least exposed to surface contamination; this is especially true when they belong to the type of deep wells in which an impermeable stratum constitutes a barrier against the pollution of the ground water. Compared with the excavated well, the driven one has the disadvantage of a lack of storage capacity, so that usually it is necessary to compensate for this defect by providing larger tanks, troughs or reservoirs which can be kept filled by a more or less continuous pumping (windmills, motor pumps).

Artesian wells supply the greatest, though not always absolute, safety against contamination from the surface.

Water Storage.—Water storage may under a number of conditions become necessary. It is usually practiced in those cases in which the source of supply is irregular or uncertain, when water is to be held for sedimentation and self-purification, when it is to be forced by pressure from an air tank or standpipes, or when a supply is to be carried in transit. Either open or closed reservoirs or containers may be used for the purpose. The former may be open vessels of limited capacity or spacious structures often requiring a considerable feat of engineering. The reservoirs formed by impounding dams may be considered to belong to the latter type.

Whatever the nature of the reservoir may be, it should have the same safeguards against surface pollution as those required for the excavated shallow well, namely, the complete exclusion of surface drainage, the selection of soil used in construction with regard to freedom from organic contamination and the use of impervious ma-

terials; in addition, both construction and site should be such as to permit cleaning.

In the choice of the smaller storage appliances, either open or closed, the question of construction material is of some importance. Unless water of a certain degree of hardness is to be stored, lead should be avoided. Galvanized iron is a rather satisfactory material for the construction of tanks; wood, although in common use for the purpose, can be objected to because of the difficulty in cleansing after contamination has taken place. Concrete is an excellent material, but it may contribute to the hardness of the water unless separated from it by a coat of coal tar.

The inner surface of containers must be as smooth as possible, and all corners should be well rounded. The construction should always be such that cleaning can be readily accomplished.

In addition to the requirements mentioned, tanks used both for storage and as drinking troughs must be so placed as to render fecal contamination by the animals impossible. A certain degree of automatic cleaning is rendered possible by permitting a constant flow of fresh water to pass through the containers of the type just mentioned.

Water Improvement.—A good part of the task of sanitary engineering is devoted to the problem of depriving bad or unsafe water of its dangerous qualities by some method of water improvement. Its success in this direction is in a large measure responsible for the sanitary safety of a great number of urban communities. For reasons already stated, the sanitary improvement of a water supply for animals has not and cannot become the prominent factor that it is in the maintenance of the health of man. Only in exceptional cases is the drinking water for animals subjected to processes of purification and then only when this does not involve a considerable outlay of capital.

Self-purification.—In the consideration of any part which water may play in the transmission or propagation of disease, the fact that the biologic causes of disease normally do not belong in water and that water is not a suitable medium for their growth and reproduction must be given due weight. The pathogenic elements for which water may serve as a vehicle are nearly all obligate parasites which without contact with the tissues of their hosts are placed at a disadvantage, as a rule quite fatal to a prolonged existence. Subjected to starvation and cold in such an abnormal medium they fail to reproduce, and in addition they are exposed to a number of conditions tending to eliminate them as factors in the production of disease.

Introduced into a large volume of water, infective material may

become diluted to a vanishing point; in quiescent water they tend to settle to the bottom, the sedimentation being greatly enhanced by the clay particles of muddy waters by which they become enmeshed.

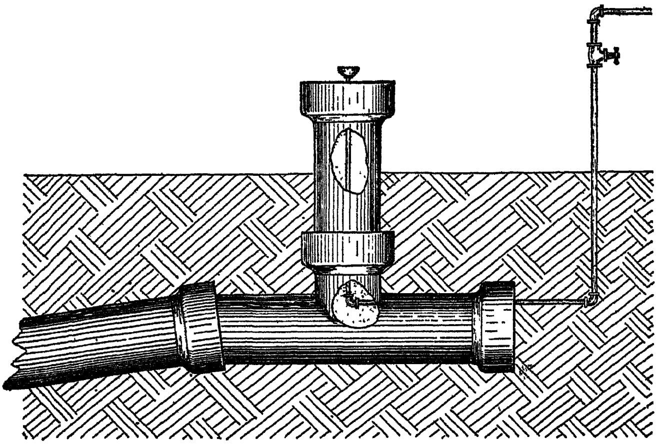

FIG. 16.—Sanitary watering device for poultry.

Exposure to sunlight likewise is apt to aid in the purification of a water through its germicidal action. Its influence is probably a restricted one, as it can be exerted only on the surface, and almost any degree of turbidity is apt to render it inactive. Oxidation not only tends to eliminate organic impurities, but can also be credited with a certain degree of germicidal action.

Most potent factors in the self-purification of water are the biologic elements which find in water their natural habitat. Saprophytic bacteria, infusoria and amebas by preying upon the pathogenic intruders will account for their entire elimination, not to speak of bacteriophages which may also be present. They are largely responsible for the fact that the microbic disease

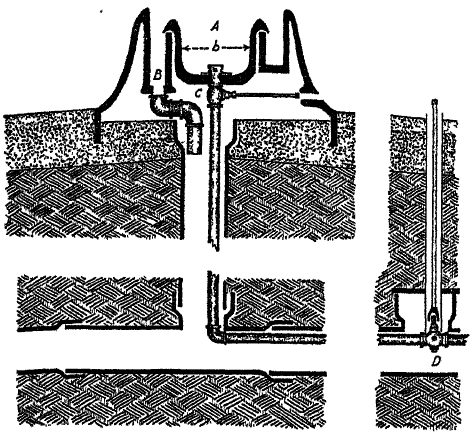

FIG. 17.—A proposed sanitary waterer for swine. *A*. Drinking cup, *B*. moat, *C*, regulating valve, *D*. stop and waste cock.

producers disappear more rapidly from heavily polluted waters than from relatively pure ones, and from stagnant water more readily than from running water.

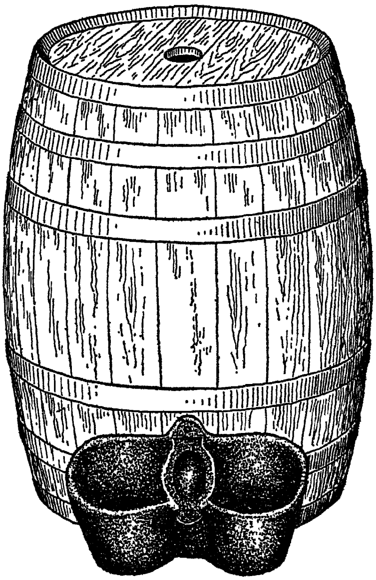

Fig. 18.—A common drinking utensil for swine.

In quiescent water, a richer, normal microbic flora and fauna are to be found than in moving water. On the other hand, moving water is not so prone to serve as a temporary medium for the eggs and larvae of helminths as is quiet water, and the parasitic elements mentioned tend to persist longer than most of the pathogenic bacteria. In course of time, however, all biologic pathogenic factors tend to disappear, so that the storage in a manner to prevent further pollution has become widely recognized as an efficient method of purification.

Distillation.—Distillation is the ideal means of water purification, but it finds only a limited ap-

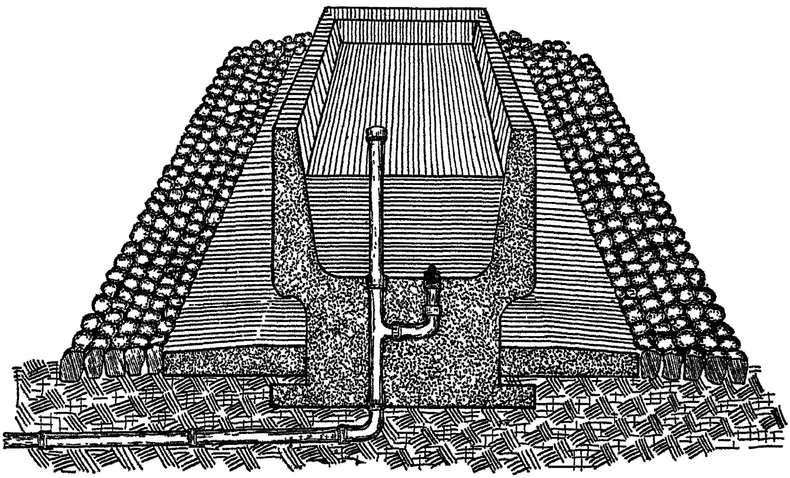

Fig. 19.—Watering trough for large animals.

plication in the hygiene of animals. Its use is confined almost

entirely to the drinking water for animals during oversea transportation.

Sterilization by Heat.—The boiling of drinking water is a measure by which a polluted water can be rendered absolutely safe, but owing to the high cost involved, it, like distillation, is but rarely practiced in livestock sanitation. When a steam boiler is available, however, the passing of steam into a well until its water is heated to the boiling-point is a highly efficient and very practical method of destroying the results of contamination. In the application of this method the boiling-point should be maintained for at least one hour. After that period the well should be pumped dry, and this alternate heating and draining may be repeated as often as is deemed necessary to render the water safe. The source of pollution, however, should always be ascertained and removed before the sterilization process is actually undertaken.

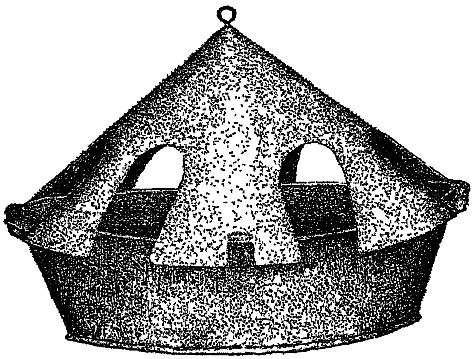

FIG. 20.—Drinking utensil for poultry.

Filtration.—The purification of a water supply for animals by filtration is practiced only in the use of a small economically constructed sand filter (Fig. 13) by which the coarser suspended impurities can be removed. Such filters can in no way be compared with the elaborate installations by which cities reduce the incidence of water-borne diseases. They must be regarded as inadequate for the removal of pathogenic microbes, but they may render a good service in the elimination of the eggs and larvae of helminths.

Disinfection.—The addition to the drinking water of chemical germicides enjoys a considerable popularity as a means of destroying disease-producing factors of a microbic nature. Among the germicides employed, permanganate of potash is perhaps the one most widely used. It acts as an oxidizing agent, and enough of it is added to the water to bring about a faint pink color. The color remaining indicates an excess of the permanganate over that required for the complete oxidation of all organic impurities. Although the complete sterilization of the water may not always be secured, the method is useful in the improvement of small supplies and may, when adequate

amounts are used, find application also in dealing with polluted wells. The germicide is commonly used in the form of tablets, but in the disinfection of wells it is preferable to use concentrated solutions of which a sufficient amount is added to slightly color the water. As the color disappears through the further influx of organic materials more of the solution may be added from time to time.

The improvement of polluted or suspected water by the addition of chlorine, either as such or in the form of calcium hypochlorite, bleaching powder or "bleach," has thus far found but little application in the practice of livestock sanitation. In the safeguarding of urban water supplies it finds a wide application and, no doubt, it may on occasions render efficient service when polluted water is to be rendered safe for the use of animals. The ordinary bleaching powder, provided it is fresh and has a chlorine content of approximately 33 per cent, is perhaps the best suited for the purpose. The dosage of chlorine varies with the character of the water to be treated, but adequate disinfection may, as a rule, be secured when 1.5 pounds of a high-grade bleach is added to 100,000 gallons of water, which expressed in terms of free chlorine amounts to about 0.5 part of chlorine to 1,000,000 parts of water. Before it is added to the water, the hypochlorite should be rubbed up and suspended in water and then be rapidly mixed with the water to be treated.

The action of the hypochlorite, as in the case of potassium permanganate, depends on oxidation. The oxygen is liberated from the water itself and not from the bleach. What happens is probably something like this:

$$Ca\left\langle\begin{matrix} OCl \\ Cl \end{matrix}\right. + CO_2 = CaCO_3 + Cl_2$$

$$2Cl + H_2O = 2HCl + O$$

The use of bleach is indicated for the purification of polluted or suspected wells and when small quantities of water are to be rendered safe. In this connection, the method used by the U. S. Army deserves consideration. A glass ampoule in which 1 gram of bleach is hermetically sealed is broken into a little water and poured into a suitable container holding 40 gallons of water. After exposure and sedimentation of not less than half an hour the water can be used.

Although nothing is very definitely known on the subject it seems doubtful that water disinfection can be depended on to destroy the

eggs and larvae of intestinal worms, however efficient it may be in dealing with the bacterial disease producers.

Elimination of Polluted Supplies.—As an adjunct to any attempt to provide a wholesome water for the use of animals the elimination of polluted supplies is of the greatest sanitary importance. The neglect of this simple detail commonly nullifies the most adequate measures taken to secure a pure water for animal use.

From a sanitary point of view, the water used by animals is never superior to the most objectionable supply to which they may have access. The advantages attached to a good well water offered to sheep practically disappear when they can also partake of the water collected in pools and puddles. A wholesome water provided for cattle and horses has but little sanitary importance when they can also drink the overflow from the trough gathered in the mudhole surrounding

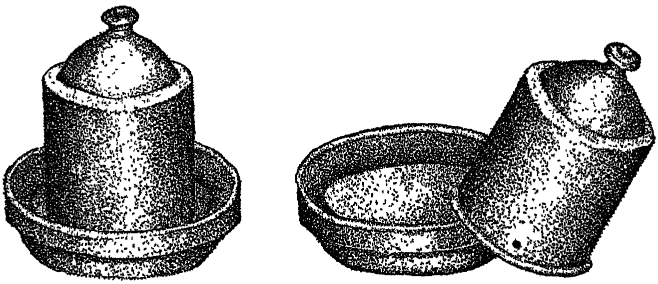

FIG. 21.—Drinking fountain for chicks.

it. Nothing is accomplished by the use of sanitary fountains in poultry yards when wagon ruts filled with filthy surface water are constantly available; and as long as swine can quench their thirst in the hog wallow, but little is gained in a hygienic sense by providing them with a more wholesome supply.

The elimination of such polluted waters by drainage, filling, or enclosure by fences is on the whole of as much sanitary importance as the adoption of the more costly methods of water improvement.

The Watering of Animals.—If at all possible, animals should be enabled to quench their thirst with wholesome water whenever they are inclined to do so and only in special cases should there be placed any restrictions on the amount taken in. The volume of water required for drinking purposes is subject to considerable variations which are largely determined by the water content of the feed, the rate of water elimination from the body (sweat) and the species of animals con-

cerned. For this reason it is not possible to state the exact amounts needed under all circumstances.

Fred Smith, basing his estimates on observations made aboard ship during the Abyssinian expedition, names the following daily amounts:

	Gallons
Elephants	25
Camels	10
Draft bullocks	6
Pack bullocks	5
Horses	6
Mules and ponies	5

The approximate water requirements by weight based upon one part by weight of dry matter consumed is about as follows: for horses 2.5 x 1, for milk cows 5 x 1, for fattening steers 3.5 x 1, for swine 7 x 1 and for sheep 2 x 1.

The amounts stated rather represent the minimum of what should be available, and inasmuch as a certain volume is required for cleansing and other purposes not less than double the quantities mentioned is to be regarded as a safe basis upon which to estimate the volume to be provided.

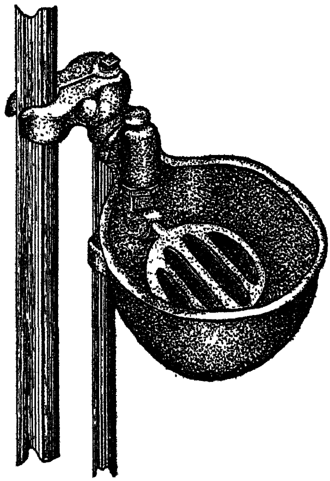

FIG. 22.—Individual drinking cup for cattle. (After "Jamesway").

The drinking water should be of sufficiently low temperature to be refreshing, without being cold enough to be chilling. A temperature ranging between 45° and 60° is most desirable. Especially in connection with horses has the drinking of cold water been regarded as responsible for certain gastro-intestinal disturbances, founder and other morbid conditions. It is quite probable that this danger has been much over-estimated and that if harm resulted at all it was due more to the volume taken in by a thirsty animal than to the temperature *per se*. Heated, tired and thirsty horses are perhaps more apt to be injured by the injudicious feeding of grain than by the drinking of cold water.

The empirical opinion prevalent among horsemen that caution is required when watering such horses cannot, however, be ignored

altogether, and for this reason the following practice may be recommended.

The horse, hot, thirsty and tired, should be allowed a limited amount of cooling drink, after which he may be given his ration of hay or other roughage. When respiratory frequency has resumed its normal rate and other marked signs of fatigue have disappeared, the animal can be permitted to quench its thirst, and when fully refreshed the grain ration may be offered.

Animals having access to water at all times will not incur any hazard from the drinking of cold water. This is the ideal method of watering and should be approached as nearly as possible in all cases.

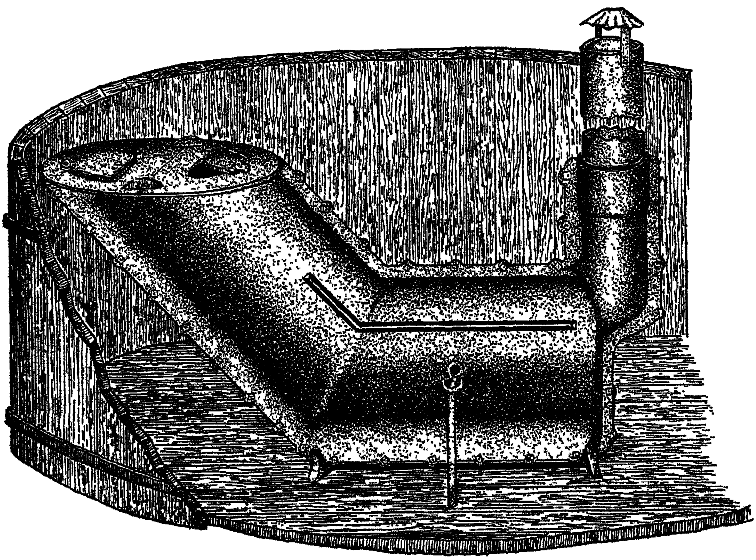

FIG. 23.—Heating device for water tanks. (After Hunt-Helm-Ferris Co.)

Utensils used for watering of animals such as troughs, pails and fountains (Figs. 18, 19, 20 and 21), must be so constructed as to promote cleanliness.

Troughs through which a constant flow of water passes are always preferable to others which serve more or less as a reservoir, although the former require a dependable and abundant supply. This type of trough should be of rather restricted capacity so as to secure frequent changes of the water. All watering devices must be so placed as to prevent direct or indirect fecal contamination.

Public watering-troughs are objectionable as they frequently serve

as distributors of infection (glanders, foot and mouth disease, strangles, infectious pneumonia). Self-cleaning devices may, however, remove this infection danger to a considerable extent.

Of particular value are the individual drinking cups provided for animals like dairy cows which are commonly subjected to prolonged periods of stabling.

All drinking utensils must be periodically cleansed and should always be so constructed as to permit thorough disinfection whenever this should be indicated.

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CHAPTER VI

FOOD

The destructive metabolism of the animal body renders imperative the constant introduction of extraneous substances. These substances serve as a source of energy or fuel for immediate use or may be stored as reserves to be drawn upon in emergencies. They replace the body substance destroyed in the metabolic processes and provide the material upon which growth is dependent. They furnish the elements which take part in the co-ordination and regulation of the complex chemical reactions which result in life.

Collectively they constitute what is known as food, and this, with its great variety of intrinsic as well as extrinsic qualities and of quantitative differences, cannot fail to influence health and body well-being in the most profound manner.

Food and nutrition have always occupied the hygienist and must continue to do so even if the science and art of feeding have gradually developed into a special branch of study and research. This specialization, above all, pertains to animal nutrition, in which economic considerations are apt to overshadow the mere hygienic aspects. This chapter is most concerned with the latter and leaves the former to be dealt with by the many excellent works on the feeding of animals now available.

Nutrient Substances.—The substances which the body requires for its growth and maintenance, for its yield of energy and produce, and for the regulation and co-ordination of its metabolism must be contained in the food and be supplied in a constant and adequate manner. They may be classified as follows:

I. Organic nutrients.
- (*a*) Nitrogenous material (proteins).
- (*b*) Carbohydrates.
- (*c*) Fats.

II. Anorganic nutrients.
- (*d*) Water.
- (*e*) Mineral salts.

III. Accessory food factors.
- (*f*) Vitamins.

Not only must the materials mentioned be contained in the food, but they must be capable of digestion and assimilation. The foodstuffs must be palatable and suited to the needs of the animal species concerned. The nutrient substances must be supplied in quantities sufficient to replace the materials manufactured by the body as produce and those destroyed by metabolic action. They must be adequate to maintain the body temperature and be convertible into the energy required for such dynamic functions as the various forms of muscular action. The food must make good the loss of water and minerals eliminated by the body and must also furnish the accessory food factors which appear to be indispensable for the proper functioning of the general process of tissue building.

Although the proportion of the various nutrients *inter se* will but rarely be a constant one, it should not be so distorted as to give rise to undesirable drafts on the food reserves stored in the body or to tax the body's compensatory capacity in an undue manner.

Organic Nutrients.—Without the fulfilment of the requirements named above, the state of nutrition, upon which undisturbed health is dependent, becomes impaired, and the animal body becomes inefficient as a producer of energy and substance.

Failure to obtain or to assimilate the nutrients needed for growth and maintenance may result in a number of abnormal conditions varying in nature with the character and volume of what is lacking in the daily food intake. These conditions may range between complete starvation or inanition incidental to the withholding of all food and the disturbances in body function resulting from the absence of one single factor of the nutritional complex.

Outright starvation of livestock is not common. It is occasionally observed in the case of animals forgotten in enclosures or accidentally imprisoned in out-of-the-way situations, and in certain morbid states which prevent prehension or deglutition or which hinder assimilation. Animals may be subjected to it during voyages and marches across long stretches of desert or when a heavy blanket of frozen snow covers the scant or weathered vegetation of a range.

Inanition results from failure in the supply of the nutrients, which forces the body to consume its own substances in order to sustain the metabolism essential to life. Under the operation of this autoconsumption, the body weight may have become reduced by from 30 to 40 per cent at the time of death, and in a measure this weight loss represents the nutritive resources at the disposal of an animal when forced to burn its own body substance. With the exhaustion of the

reserves, the required degree of body temperature can no longer be maintained, the most vital functions default for lack of material fundamental to their performance, and a general state of inanition inaugurates the progressive failure of cardiac and respiratory efforts and of other functions imperative to life.

In actual starvation, as well as in mere underfeeding, the failure of the supply of nitrogenous nutrients plays an important part. Not only are these essential as tissue builders in construction as well as in reconstruction, but to a degree they may be drawn upon as sources of energy and fuel. In the carnivora they may even supply the entire food demand, but in the herbivora, they can do so only in part, owing to the more limited capacity of the digestive organs for this type of nutrient material.

In the herbivora the intake of carbohydrates and fats is more essential to body maintenance, not only as a source of energy, but also because they tend by their metabolic dissimilation to retard and to reduce the destruction of the proteins needed for tissue upkeep. In the absence of the nitrogenous nutrients, fats and carbohydrates cannot indefinitely prevent the inanition incidental to protein starvation. They merely postpone it by husbanding the supply present in the body.

Although actual starvation through the complete lack of nutriment is not common enough to require special mention from a hygienic point of view, the occurrence of a partial starvation or underfeeding is frequent enough to warrant consideration. This comes about through a variety of causes, among which the following must be given recognition: First, lack of soil fertility, crop failure, and the scarcity of food by acts of war; second, injudicious or faulty feeding involving disregard for the nutritive requirements of the animals concerned; third, the spoiling of the food, bringing about the destruction of the nutrients by saprophytic action, or the leaching of forage plants during extremely wet seasons.

Underfeeding must be regarded as incomplete starvation; it does not lead to death in a direct manner, but the animals affected lack body vigor, they are apt to be poor in flesh and deficient in the production of meat, fat, milk, wool, or eggs. In work animals the labor output is reduced by the inability of the muscles to translate substance into dynamic energy, and in severe cases, pregnancy may be terminated by fetal death. The underfed animal is more susceptible to a number of microbic diseases and apparently is the most favored host of parasites external as well as internal.

It is probable that injudicious food selection and disregard of the nutritive requirements of the animals concerned are the most prolific causes of undernourishment, and that a deficiency in the nitrogenous constituents of the food is a chief factor of mischief. The nutritional requirements must necessarily vary with the specific breed and age as well as with the purpose for which animals are maintained, but protein deficiency will ordinarily be prevented if 1 pound of digestible nitrogenous nutrient is provided for every 8 or 10 pounds of the non-nitrogenous, the amount of which fluctuates with the mechanical performance of the body or its yield or storage of animal products.

In addition to the nutritional value of the food, consideration must be given to its volume. If the food is too concentrated and reduced in volume, the digestive tract does not become sufficiently filled for the peristalsis to bring about a continuous propulsion of the food mass through the tube, and the stimulus to intestinal contraction furnished by the contact of its ingesta with the mucosa is in a measure also lacking. On the other hand, the feeding with excessively bulky foods causes over-distention of the organs and increased strain on the abdominal wall, which, in turn, may give rise to a yielding of the vertebral column (sway back) and to an abnormal prominence of the abdomen (pot-belly, hay belly). The encroachment of an overfilled digestive tract on the diaphragm may likewise constitute an impediment of the respiratory function.

The volume of food is determined by the amount of dry matter it contains. Roughly estimated, this ranges between one-sixtieth and one-fiftieth of the body weight per day in the young and between one-fortieth and one-thirty-third of that of adult herbivora. A considerable portion of the dry matter is supplied in the form of hay or other roughage which, in horses, cattle and sheep, for instance, may amount to 1, 1.25 or 2 per cent of the body weight.

Although the selection of the foodstuffs from an economic point of view lies outside the scope of this discussion, the following table, based on data supplied by Moyano y Moyano, may serve as an indication of the approximate requirements of certain classes of livestock. (See p. 126.)

Habitual overfeeding of animals is less common than underfeeding. A distinction must be made between overfeeding and overnourishment. Although the two conditions may overlap in their results, the former pertains more particularly to the more acute excesses in eating and the latter to the sequels of digestion and absorption of more nutrient material than the body requires or what it should nor-

NORMAL, DAILY NUTRIENT REQUIREMENT PER 1000 LB. OF LIVE WEIGHT

Type of animal	Total dry matter, lb.	Protein, lb.	Carbohydrates, lb.	Fat, lb.
Horses at light work	22.5	1 8	11.2	0 6
Horses at heavy work	25.5	2.8	13.4	0.8
Work oxen at rest	17.5	0.7	8.0	0.15
Fattening steers	27.5	2.5	15.0	0.5
Milch cows	24.0	2.5	12.5	0.4
Sheep, fattening	26.0	3 0	15.2	0.5
Lambs (5 to 6 months old)	28.0	2.2	15.6	0.8
Lambs (yearlings)	22.0	1.4	10.4	0.3
Hogs (fattening)	36.0	5.0	27.7	
Shoats (5 to 6 months)	31.5	4.3	23.7	

mally store up or yield as desirable products without giving rise to pathologic conditions or processes.

In overfeeding or overeating the animal takes in more food than its digestive organs can normally dispose of, and as a result the food mass becomes subject to putrefactive or fermentative processes leading to various digestive disturbances or to intoxications immediate or remote in their effects (colic, bloat, founder). They are of more serious import in the herbivora than in the carnivora and omnivora, and this is to a large extent due to the fact that the latter are more readily incited to vomition, a corrective action of which the former cannot usually avail themselves.

The absorption of excessive amounts of the organic nutrients is in a large measure prevented by limitation of the digestive capacity of the animal. The surplus is evacuated with the feces, either in an unchanged condition, or decomposed by putrefactive or fermentative action. In the latter state the materials produced may bring about in a less acute manner the same morbid conditions seen in simple overeating. In accordance with individual characteristics the excess of food may, however, become digested and absorbed and wholly or partially assimilated. In such cases, it may give rise to obesity, gout and other morbid conditions.

Proper rationing of the food supplied and the adoption of sane feeding practices thus are essential from a hygienic point of view.

Anorganic Nutrients.—For the maintenance of animal life and health the organic nutrients alone are not sufficient. They must be sup-

plemented by water and by mineral substances, imperative factors in the structural as well as in the functional requirements of the body. In another chapter consideration was given to the hygienic aspect of water, which will not need to be repeated.

The mineral nutrients must be constantly and adequately supplied, because without them life cannot be indefinitely maintained. These substances enter into the structure of the tissues and are indispensable in many of the physiologic functions as carriers of gaseous products, as factors in the control of muscular action and other biochemic processes. They make possible the movement of fluids (osmosis), play a part in the coagulation of the blood, and in the solution and digestion of proteids and fats. The optimum degree of alkalinity or acidity is maintained by them, and harmful products of metabolic dissimilation are neutralized by their presence.

Anorganic nutrients are derived from the food from which they are absorbed along with the digested organic matter. Amounts in excess of physiologic requirements either fail of absorption and leave the body with the feces or are eliminated as a constituent part of the urine. The minerals retained are utilized in the structural and functional requirements of the body, including the fetus *in utero;* as integral ingredients of the milk, they supply the needs of the growing young animal during its nursing period.

After the dissociation of organic compounds of which they form part or during which they are formed, they are removed by the excretory organs. In this manner there comes about a definite mineral cycle which, for its maintenance, is dependent on a more or less constant intake of the various organic and anorganic salts of the physiologically essential elements.

These are known as biogenic elements, and they include sodium, potassium, calcium, magnesium, phosphorus, iron, chlorine, iodine and probably fluorine and silicon as well. Many other elements enter the body with the food and may be recovered in the ash, but as little is known of their physiologic importance, they cannot be intelligently considered in connection with the hygiene of nutrition. The biogenic elements are contained in the food in varying amounts in accordance with the species of plants involved, their parts, the soil in which they grew and with climatic conditions.

Most foodstuffs are deficient in sodium and chlorine, so that these elements must be especially provided in the form of sodium chloride, but potassium is found in sufficient quantity in roots and tubers, in the seeds and other parts of the legumes, in bran, in the oleaginous

seeds and in food of animal origin (milk, meat). Leached forage plants, however, are commonly deficient in potassium.

Lime and magnesium are present in sufficient amounts in the better types of hay and green grasses and in the clovers, but most grains, straws, roots and tubers, as well as the prairie or wild hays, are poor in calcium. The small amount of iron required by the animal body is adequately supplied by most forage plants; the same is true of iodine, if the soil in which they grew is not depleted of this element.

Phosphorus, as phosphoric acid in organic compounds, is abundant in the better types of green feed and hay, in various seeds and bran and in the foodstuffs of animal origin. Cereals and straw are poor in phosphorus.

With a diet on a variety of foodstuffs, the required mineral substances are usually adequately supplied. Only when the ration is made up of one or more improperly selected foodstuffs, or when the soil in which they grew is impoverished in the essential elements, may there come about pathological conditions in the animals fed with them.

The modus operandi of these so-called deficiency diseases or mineral starvation is not always thoroughly understood, but empirically acquired knowledge as well as certain experimental evidence leaves no doubt in regard to the principal etiologic factor.

Mineral starvation, coming about either through a failure in the supply or through inability to assimilate anorganic nutrients, is apt to lead to such conditions as pica, cachexia and the complex of pathologic processes in bones and joints of which rickets, osteomalacia and atrophy are the better-known types. Although it is not always possible to eliminate the deficiency in other biogenic elements as a causative factor, there is reason to believe that an inadequate supply of calcium-phosphorus food constituents or the absence of the factors instrumental in their utilization is responsible for the bone and joint disturbances mentioned.

Lime-phosphorus deficiency occurs more or less sporadically in all species; its results are especially encountered in young swine as "posterior paralysis" or "rheumatism" and in chicks as "leg-weakness"; this lack also appears to give rise to the "loin-disease" of cattle peculiar to certain North American ranges, and to the "lamziekte" of the African veld. In the latter disease, the cattle, suffering from a form of pica, as a primary effect of mineral starvation, are fond of chewing the decaying bones scattered about the range, in which anaerobic saprophytes produce toxic substances fatal

to the animals in a manner comparable to the effects of botulism. There is reason to believe that the feather-pulling habit of fowls and the wool-eating vice of sheep, at least in part, are induced by the same type of mineral starvation.

It is known that the absence of the small quantity of iodine required for the performance of the thyroid function may give rise to a series of morbid conditions associated with goiter as the more constant result of this deficiency. Goiter in man and animals is narrowly confined to certain regions with a low iodine content in its soil and water. In the United States the Great Lake region and a large area of the northwest are noted as goiter territory; this pertains to animals as well as man. In some of those parts, goiter is a common disorder, with hairlessness of the new-born as a characteristic feature. This morbid state has been definitely shown to be associated with an iodine deficiency of the food of pregnant animals; when this fault is corrected by adding iodine to the ration, the offspring is apt to be entirely normal at birth.

Sodium, especially in combination with chlorine, is indispensable to the functioning of the body tissues and organs. Sodium chloride is the source of the chlorine of the hydrochloric acid of the gastric juice, and its deficiency is apt to lead to digestive disturbances. Sodium, as well as potassium, is essential in the regulation of muscular function, and it plays an important part in the maintenance of osmotic pressure and of the alkaline reserves. Its withdrawal from the body, in the face of a failing supply, may be followed by the solution of a corresponding amount of the total ash of the skeleton, including the calcium-phosphorus constituents.

The greater part of the mineral deficiencies of the food arises from a similar defectiveness of the soil which produced the forage plants involved. A logical means of prevention, thus, would be the amelioration of agricultural or pasture lands by suitable fertilization. As this is not always possible or economically practicable, and as moreover the deficiency may arise purely by the selection of the food in which costs and profits are factors of dominant importance, it frequently becomes necessary to meet a given lack of anorganic nutrients by supplying them as supplements to the daily ration. Except in regions in which the drinking water is more or less brackish, common salt must always be provided in a special manner. It may be mixed with the feed or the animals may be allowed free access to it, or both methods may be used at the same time. When mixed with the feed from ½ to 1 per cent in weight is added to the concentrates, and if,

in addition, pieces of rock salt or compressed salt blocks are available to the animals, the sodium and chlorine requirements will be fully met.

Calcium, phosphorus and magnesium are especially essential as ingredients of the food for heavily producing cows in order to prevent overdraft on those elements as stored in the skeleton. To such animals they may be furnished in the form of finely ground bone meal (steamed) so that each cow receives from 2 to 6 ounces per day. Even after the period of profuse lactation is passed, this supplement should be continued in order to permit the building up of adequate reserves before the following lactation period. This restoration of the mineral stores is further enhanced by a non-producing interim between lactation periods.

Swine, on an exclusive grain ration, may likewise require a mineral supplement. This is commonly provided in the form of wood-ashes or charcoal which, however, beneficial, are not always adequate. A mixture of 9 parts of steamed bone meal and 1 part of tankage, to which the animals have free access, will usually furnish an adequate supply. The addition of calcium carbonate in the proportion of 2 per cent of the ration was shown to prevent the bone and joint disease complex in growing pigs. In this connection it should be pointed out that the addition of lime and phosphorus may not always be followed by the desired results unless the utilization of those elements is made possible by the action of short-wave radiation or of the anti-rachitic vitamin. That deficiencies in the ration of pregnant animals may play a part in producing morbid conditions in the offspring has been amply shown. It is not impossible that the young of such dams are more or less permanently impaired no matter what corrective may be used later.

For poultry, in which lime depletion may lead to a morbid process which is especially expressed as "leg weakness," the use of oyster shell appears to be an adequate means of supplying calcium. In these animals vitamin and radioactive influences are also potent as factors in the assimilation of the elements supplied.

In the feeding of all animals the mineral ingredients of the ration must be given consideration from a hygienic point of view. Not only may the bone-forming calcium-magnesium-phosphorus complex have to be provided (bone meal), but the mineral base of the food should be present in a considerable excess and should, at best, correspond to the amount of protein consumed as the principal source of mineral acids of the body.

Whenever the goiter complex among the new-born indicates a deficiency in iodine, the latter should be added to the ration of pregnant animals. Not more than 2 grains of potassium iodide per day supplied to sows during the gestation period appears to be sufficient as a preventive of goiter and hairlessness in the pigs. Similar results can be obtained in other animals if the amount of the iodide bears the same relation to the body weight.

Accessory Food Factors.—A considerable volume of experimental evidence shows conclusively that, in addition to the organic and anorganic nutrients, animal life is dependent on certain substances, which, when present in the food, appear to exercise a definite influence on the maintenance of the body in a normal state. Although they are chemically unidentified, and their existence and specific function are revealed only by what results from their absence or elimination, nevertheless, they appear to be quite indispensable to normal life. They are designated as accessory food factors or vitamins. The ones now known must be mentioned.

Vitamin A is abundantly present in milk, butter, egg yolks, and in a less degree in many vegetable foods, green leaves and in the embryo of many seeds. It is absent in cereals (yellow corn excepted), certain varieties of peas, millet, soy beans and straws. When present in the ration it tends to promote growth and to prevent xerophthalmia and damage to certain epithelia.

Vitamin B has a wide distribution in nature. With vitamin A it occurs in the yolk of eggs and milk and in many glandular organs of the body. Yeast is rich in this vitamin. Cereals contain it only in the outer layers, and hence it is absent in patent flour and polished rice. Leaves, twigs, roots and fruits of living plants contain it. Its continued absence from the ration of certain animals may give rise to morbid neuro-muscular phenomena (beriberi in man, polyneuritis in fowls). Hence it is also designated as the anti-neuritic vitamin.

Vitamin C is contained in fresh vegetables and the juices of such fruits as oranges, lemons, grapes and tomatoes. When persistently absent from the diet of man, monkeys and guinea-pigs, a pathologic state may arise characterized by multiple hemorrhages in the loose subcutaneous connective tissues and the fasciae by swelling and bleeding of the gums and other phenomena associated with scurvy. This vitamin, thus, is anti-scorbutic in its action.

Vitamin D was for some time confounded with Vitamin A, but it is known now to be a distinct entity among the accessory food factors. It is found in butterfat and cod-liver oil, but ordinarily the

vegetable oils do not contain it. It is anti-rachitic in its action, and it serves as a factor which helps to determine the assimilation and further utilization of the calcium. This action appears to be identical with that of ultra-violet radiation, and the vitamin itself is probably a substance (cholesterin?) activated by radiation and thus rendered capable of playing an as yet unidentified part in mineral metabolism.

Vitamin E is to be found in a large assortment of foodstuffs; it was experimentally shown to be abundant in green lettuce leaves, in the seedlings of Canadian field peas, whole oats and wheat, in egg yolk, meat and beef liver. The embryos of wheat have a remarkable potency, whereas patent flour and milk apparently are devoid of this vitamin. Its action is associated with the reproductive function and apparently has to do with the growth and preservation of the embryo. Its absence does not prevent normal ovulation, impregnation and implantation, but appears to result in the resorption of the embryo.

Important and interesting as the knowledge of the nature of the accessory food factors may be from a physiologic point of view, it does not appear that harm resulting from their absence is common among livestock. In fact, it seems difficult for animals fed on the ordinary varieties of food to escape an adequate daily amount.

An exclusive grain ration in which yellow corn forms no part may bring about a vitamin A deficiency disease adversely affecting growth or may cause a roup-like disease of fowls observed by Beach, and it is not impossible that some of the paralyses of poultry may be attributed to a lack of vitamin B in a poorly selected ration.

Scurvy is not observed in farm livestock, but may be particularly disastrous in guinea-pigs when they are fed on a dry ration for too long a period. The feeding of green leaves such as lettuce, cabbage or sprouted oats is an effective preventive of this disease.

It is probable that a vitamin D deficiency disease *per se* does not commonly occur, and that the abnormalities of the skeleton are more apt to be due directly to calcium-phosphorus starvation and to failure of exposure to ultra-violet radiation than to a lack of the anti-rachitic food factor. It must be admitted, however, that his lack may exercise a valuable influence when prolonged cloudy weather and indoor life deprive young animals of the required exposure to direct solar radiation.

Hygienic Aspects of Certain Foods.—It is obvious that adequate nutrition and a wholesome quality of food are fundamental to the maintenance of the animal body in a state of health, but in addition

to this, consideration must also be given to peculiarities of certain foodstuffs as well as to their application which, though not to be regarded as defective, are, nevertheless, hygienically important.

Changes in Diet.—An abrupt change from an accustomed feeding régime to another is not always well tolerated by animals, even if no fault can be found with the food offered. Apparently the digestive organs and their function adapt themselves to the digestion and utilization of a given type of food, and when the accustomed ration is replaced by another one, they are apt to react in a manner momentarily upsetting the hitherto normal alimentary processes.

A sudden change from a dry feeding régime to a green one, and vice versa, may lead to such manifest disturbances as diarrhea or constipation, colic and bloat, and for some time the general state of nutrition may not be maintained at the previous level so that, temporarily at least, the animals may lose some of their weight.

Changes to an unaccustomed food or feeding régime should therefore be made in a gradual manner. This is accomplished either by slowly replacing the constituents of the former ration by increasing quantities of the new one or by carefully alternating the two types of food offered until the digestive capacity has adjusted itself to the new régime. Usually from four to seven days are required to bring about the desired change without disturbing results.

Consideration must also be given to the nutritive requirements of the animal body in accordance with the demands made on it. This is of especially marked hygienic importance in work horses needing heavy grain rations in order to sustain the dynamic output of muscular activity. If this activity is abruptly suspended for some length of time, perhaps because of holidays or periods of bad weather requiring cessation of the accustomed labor, and if the heavy feeding is continued during such an interim, metabolic disturbances are apt to come about which express themselves as azoturia or "Monday morning disease," a morbid state justly feared by owners of work horses. In the prevention of this disease, the material reduction in the amount of concentrated food offered is the most potent of all measures, and this cannot be neglected with impunity.

Age of Food.—The age of the food is not always without influence on the well-being of the animals which must be sustained by it. Hay and grain more than one or two years old have commonly lost some of their nutritive value; also new hay and oats, in which the process of maturing, fermentation or sweating has not yet been completed, are properly objected to by experienced feeders. In the agricultural

section where corn (maize) is commonly used as feed for horses, veterinarians are wont to look upon the period when the new corn becomes available as one during which colic cases are most numerous.

It is possible that such factors as improper harvesting and injudicious feeding, also exercise an influence, but there scarcely can be doubt that recently harvested grain and newly made hay should be avoided as food until the sweating process has been completed. This is consummated when the mass has become thoroughly cooled.

New hay is laxative, and freshly harvested oats and corn are less digestible and may give rise to various digestive disturbances accompanied or not by colic. As a rule, it is best to allow three or four months for the maturing of such foodstuffs before they are supplied to the animals. When circumstances compel their use the change of food should be gradual, and small quantities must be offered in the beginning.

The presence of a certain quantity of new grain in the stubble fields, commonly used as grazing ground for sheep, is a reason for caution as it is frequently responsible for the occurrence of bloat and of other morbid gastro-intestinal conditions.

Food and Choke.—Certain physical properties of food may give rise to esophageal obstruction or choke. The rapid eating of very dry grain may result in impaction of the crop of fowls, and dry hay quickly taken in by thirsty horses has been recognized as a cause of choke by becoming lodged in the gullet. Imperfectly masticated and insalivated food rapidly consumed by hungry animals may lead to the same consequences and has also been associated with the causation of other digestive disturbances.

As a cause of choke in cattle, the nature of the morsels which the animals attempt to swallow plays an important part. Large pieces of beets, turnips, potatoes, and similar foodstuffs frequently figure prominently in the production of mischief.

Such foods require to be pulped, chopped or otherwise divided; as a further precautionary measure, it is recommended that the animals, while partaking of this type of food, should have their heads tied low enough to prevent their being raised above the point permitting large, individual pieces to pass over the root of the tongue by gravitation.

Food Peculiarities of Hygienic Importance.—Certain foods otherwise excellent and of marked value require mention on account of more or less specific qualities with which they are endowed.

The various kinds of bran, when used habitually and in considerable amounts, are reported to cause or to favor the formation of

enteroliths in horses and urinary lithiasis in sheep. A form of osteoporosis in horses is known as "bran disease," although it is not impossible that the etiologic factor may have to be looked for in another direction.

Potatoes used here and there as a food for livestock may give rise to intoxication, if the tubers have sprouted or if they are fed in an immature condition. This is to be ascribed to the glycoside solanine which even cooking cannot readily remove. Green or immature potatoes and sprouts should always be removed before this foodstuff is offered to animals.

Photodynamic substances present in many plants used as food are responsible for a sensitization to direct sunshine expressing itself by cutaneous eruptions and erythema in the animals fed with them. Buckwheat in particular is apt to give rise to this phenomenon (fagopyrism). The grain as well as the green plants and the straw are apt to produce this condition, and animals sensitized by this food and exposed to solar radiation develop the eruption in the non-pigmented parts of the skin. This may be prevented by stable feeding or by keeping the animals in shady places during the buckwheat-feeding régime.

The presence of a toxic substance, gossypol, in cottonseed meal, demands prudence in the use of this otherwise valuable concentrate. Cautiously fed in limited quantities conjointly with other foodstuffs, it can be safely consumed by adult cattle, sheep and horses, but young calves and swine are especially susceptible to this intoxicant, and feeding allowances of from one-quarter to half a pound per head per day have been observed to be fatal to calves. The toxic agent appears to be cumulative in its action, the first evidence of the intoxication in swine becoming manifest in from six to eight weeks after the cottonseed meal is added to the ration. Steers closely confined and heavily fed with it are affected by the poison after a period of approximately three months. Certain individual swine are apparently quite resistant to the poison. Thorough cooking of this food seems to reduce the hazard associated with it, and the heat to which the cottonseed is subjected during the extraction of its oil is probably in a large measure sufficient to remove the danger which may be associated with the feeding of the by-products of the oil mills.

The tendency on the part of green forage to cause tympanites or "bloat" in the ruminants attaches a particular hygienic interest to this type of fodder. Under certain conditions, all green plants taken in as a food may give rise to the formation of gases and their accumu-

lation in the rumen as a result of their liability to rapid decomposition.

The danger of acute tympanites is above all associated with the feeding of the legumes such as clover (*Trifolium*), alfalfa (*Medicago*), and sweet clover (*Melilotus*). In animals not accustomed to this type of forage the liability to bloat is particularly marked. This danger is especially to be considered when the plants are of luscious and rank growth and when the foliage is either frosted or wet after rain or dew. Warm, humid atmospheric conditions appear to promote the rapid decomposition of the foliage, and the greedy eating by hungry animals materially increases the "bloat" hazard.

The quantity of the food taken in, however, is not always a determining factor, for in fatal cases of "bloat" sometimes occurring within a half hour after the animals were turned into clover, the amount of food consumed was found to be comparatively small.

The danger connected with acute tympanites may be reduced by certain preventive measures. Animals not accustomed to being pastured on the legumes named should at first be kept at pasture for brief periods only. They should be amply fed on dry roughage before being turned into the pasture, which should, under no circumstances, be used when the foliage is wet with dew or rain. It is always advisable to keep available for the animals regularly at pasture a supply of dry roughage.

Animals first turned into the pasture should be under supervision for an hour or two in order to make possible their prompt removal if a case of bloat occurs and in order to have some person in attendance to take such measures of relief as the situation may warrant. On farms where cattle and sheep are habitually pastured on the legumes one or more trocars should be kept in readiness for the purpose of emergency treatment.

It is possible that the seeding of certain aromatic plants (caraway) in the pastures may be helpful in somewhat reducing the risk of tympanites.

The formation of hydrocyanic acid, a phenomenon observed in a large number of plant species, is of especial importance when those serving as food are involved.

The circumstances under which the poison is formed in food plants are not always clearly defined, but in some very conspicuous examples the evidence tends to show that, when normal growth and other physiologic processes are interrupted by such influences as drouth or frosting, the danger of the plants becoming poisonous is the greatest.

The sorghums crippled in their development by lack of moisture are notorious for the hazard which accompanies their use as food for animals, and the second growth of this type of forage killed or injured by frost can be justly held to be responsible for even a greater number of calamities.

The seeds of late flax, overtaken by early frost when the bolls were still green, have been found to contain marked quantities of prussic acid, and fatalities after their use as a food have been common in certain districts.

Forage plants and their seeds in which prussic acid is apt to form should always be fed with extreme caution whenever their normal growth was arrested by adverse influences. In the case of the sorghums, it is apparent that drying and maturing result in a reduction of the amount of prussic acid, so that even though this substance may not be entirely eliminated, such foods are always safest for use after several months' storage. The fact that the presence of certain sugars (dextrose) apparently inhibits the liberation of the intoxicant in the stomach suggests the possibility that the feeding of concentrates in advance of that of the suspected fodder may also tend to reduce the danger. As the hazard connected with this type of food is never negligible, it seems prudent to subject one or more animals of inferior value to a series of test meals before more valuable livestock is exposed to the risk.

Animals pasturing in fields of standing cornstalks (maize) after the grain has been collected are apt to incur a fatal disorder well known in the corn-growing regions under the name of "cornstalk disease." Although its cause is entirely unknown, there are ample indications that the vegetation in such fields, most probably the stalks themselves, undergo some change when they are permitted to remain in the field which leads to the formation of an extremely toxic agent. Animals may succumb to this within a few hours after having been turned into the stalk field, and deaths occurring in such fields may come about from time to time during several months, indicating seemingly that either this poison is associated with only a comparatively small part of the forage or that it keeps on forming for a considerable period. It is by no means impossible that this "cornstalk disease" is no more than a penalty for the consumption of a food-stuff in process of decay.

If the corn is cut early, shocked and properly cured, its use as a food is not accompanied by danger. This method of harvesting or the use of the forage as ensilage is, no doubt, the most dependable

measure to make this food available with entire safety. Not all fields are dangerous, and the prevalence of cornstalk disease is more common during certain seasons than during others, but on the whole, the risk of loosing animals is so considerable that it is doubtful that the advantage offered by this method of pasturing outweighs the losses incurred. When in years of scarcity this food must be used, the safety of the fields should be ascertained beforehand by some less valuable animals being turned in for a feeding test. The feeding of a grain ration prior to allowing cattle and horses to enter the stalk fields has also been recommended as a means of reducing the hazard but must be regarded as of doubtful value.

Spoiled Food.—The deterioration to which food, as perishable organic material, is subject, has frequently been held to be responsible for abnormal conditions and phenomena arising in animals fed with it, and an abundance of evidence supports this belief. However, it cannot be maintained that the knowledge pertaining to the influence exercised by the many factors responsible for the changes mentioned is in a very satisfactory state. Conclusions are commonly based on circumstantial evidence only, and even when the subject is considered in the light of experimental inquiry, the facts observed do not always point to a final disposal of the problem.

The profusion of contributory factors which are apt to influence the ultimate results and the impossibility of controlling their action render it exceedingly difficult to determine, with any degree of precision, the hygienic status of foodstuffs more or less altered by the various types of organic decay. Nor is it possible correctly to evaluate the properties of the enormously large number of biologic factors or their products which are bound to be found in and associated with the food which serves as their vehicle for entering the animal body. In spite of the lack of definite information pertaining to the dangers which may or may not be associated with the feeding of materials altered in the process of decay or by the addition of foreign biologic elements, the many observations, even the inconclusive ones, cannot safely be disregarded.

Spoilage of food is the result of the action of biologic agents which destroy or alter its substance, and which, by their presence and vital activities, may impart to it qualities which may or may not exercise harmful influences subsequent to their introduction into, or their contact with, the animal body. The biologic factors which bring about the deterioration of foodstuffs are both of vegetable and

of animal origin, and may be active either as parasites of the living, growing plants, or as saprophytes after they are harvested or stored.

Parasitic factors responsible for food spoilage include the fungi associated with plant diseases. Conspicuous among them are representatives of the genera: *Phytophthera, Peronospora, Ustilago, Tilletia, Urocystis, Puccinia, Uromyces, Erysipha, Diplodia, Pseudopeziza, Cercospora, Fusarium, Gloeosporium, Scolecotrichum, Helminthosporium, Phyllachora, Polydesmus, Epichloe* and *Claviceps.*

Many foods when conspicuously infested with species of the genera named have at one time or another been regarded as the causes bringing about disturbances associated with the alimentary tract, kidney disease and many other phenomena. As similarly affected foodstuffs are commonly consumed by animals with impunity, their deleterious influence does not appear to be a regular feature, and it is by no means certain that other less conspicuous biologic factors (bacteria) do not, as mere secondary invaders, confer upon the food the qualities which may render them unwholesome or even dangerous. At least, it seems very difficult to convict the parasitic fungi *per se,* by experimental attempts. From a hygienic standpoint, it may, however, serve a useful purpose to take cognizance of a few instances in which affected foodstuffs have rightly or wrongly been associated with disturbances of animal health.

Potato vines affected with late blight (*Phytophthera infestans*) are mentioned as capable of giving rise to digestive disturbances, and the rotten tubers have apparently caused gastro-enteritis in the animals which consumed them in quantity.

Ustilago is probably of no hygienic importance although frequently looked upon with suspicion. Feeding experiments with the spores of corn smut, in which the animals were induced to eat enormous quantities, yielded negative results, and during a study of suspected anaphylactogenic properties of this material, the author injected a large volume into horses intravenously without causing the least disturbance.

Bunt or stinking smut (*Tilletia*) of certain cereals, also mentioned as a possible source of mischief was experimentally shown to be entirely harmless. Rust spores have been accused of causing disease in lambs, and *Uromyces occultus* has been looked upon as the etiologic factor of stomatitis, but the evidence in regard to the toxicity of *Uromyces* and *Puccinia,* if not defective, is at least very incon-

clusive. Fodders heavily infested with these fungi are so commonly consumed by animals with entire impunity that their harmlessness appears to be well established.

The hygienic importance of the mildews (*Erysiphae*) is uncertain, and the same may be said in regard to *Diplodia,* although, in a South African account, the feeding of corncobs infested with *Diplodia zea* is mentioned as a cause of a disease of cattle characterized by paralysis and inco-ordination of movement.

Polydesmus exitiosus has been associated with the production of a vesicular stomatitis and a dermatitis of the lower extremities of sheep pastured in rape fields. To what extent the rubifacient substances contained in the normal foliage of such Cruciferae as rape may have been factors does not appear in the evidence.

The occurrence of irritation or even ulceration of the skin and certain mucosa of animals at pasture has been attributed to foliage heavily infested with such fungi as *Epichloe, Phyllachora, Helminthro-sporium, Cercospora, Pseudopeziza, Fusarium, Gloeosporium, Scolecotrichum* and others, but the evidence presented is entirely circumstantial.

More definite knowledge has been acquired in regard to food infested by *Claviceps purpurea,* but even in this instance, feeding experiments indicate that the danger arising from this source is not always a constant one. The fungus is the cause of ergotism in a long series of graminaceous plants, including such cultivated species as rye, barley, wheat, oats and many meadow and pasture grasses. In spite of a number of negative experimental results, the toxic character of ergot has been well established, and grasses and grains conspicuously affected are commonly and correctly mentioned as the cause of gastro-intestinal disturbances, gangrene of the skin and other parts, abortions, and phenomena associated with the central nervous organs. Cattle and fowls appear to be most susceptible. The former may become poisoned at pasture when after a wet season the grasses have become heavily infested or if fed with the hay prepared from them. The accumulation of ergot seeds and grains in the débris under mangers and hay racks often plays a conspicuous part in bringing about the intoxication. Fowls fed for a certain length of time on foods prepared from grain containing ergot may develop a dry gangrene of the comb and of the toes.

Saprophytic Factors.—Depending largely on the moisture content of stored foodstuffs, spoiling by saphrophytic factors is of common occurrence, and the noxious qualities which may thus be engendered

are, on the whole, more worthy of consideration than those attributed to the parasitic fungi.

The biologic factors involved in the spoiling of stored foods are for the larger part molds belonging to the genera *Mucor, Aspergillus* and *Penicillium* and a great number of saphrophytic bacteria. Not only are some of the molds able to assume pathogenic properties when introduced into the animal body, but toxic qualities have been associated with some of them. A very marked toxicity may be attributed to certain foods spoiled or altered by bacterial action.

Two distinct poisons have been demonstrated to exist in cultures of *Aspergillus,* one capable of bringing about tetanic contractions and convulsions and the other having a depressant action.

Spoilage of mycotic origin apparently does not constantly result in the formation of toxic substances in the food, and as in the case of materials altered by the phytopathogenic fungi, a mass of very contradictory evidence on the subject has accumulated in literature. At least part of the difference of opinion on the subject may be due to the fact that the molds involved do not produce toxic agents during winter, but only in the warmer seasons.

Regardless of the fact that foodstuffs more or less changed or deteriorated by molds are often eaten by animals with apparent safety, it would be foolhardy not to consider the many fatalities among livestock which could, with a marked degree of accuracy, be attributed to that type of spoilage. The morbid conditions which have been attributed to moldy or musty food are many and include paralyses of various parts in horses, gastro-enteritis, hepatic cirrhosis and diabetes insipidus.

Bacterial decomposition of animal foodstuffs such as meat or milk may result in gastro-enteritis of the animals fed with them. Some of the bacteria involved in the putrefaction of foods are the producers of extremely potent toxins, among which the one formed by *Bacillus botulinus* is, no doubt, the most conspicuous example. This organism is saprophytic not only in animal foodstuffs but in the forage fed to farm livestock as well. It has been identified as the cause of at least a number of outbreaks of so-called forage poisoning of horses.

Associated with mycotic deterioration and toxic action are the bad results following the prolonged feeding of spoiled, sweet clover (*Melilotus*) hay. The rank growth of the sweet clover plant and its heavy, thick, stalks impede a proper curing of the hay. The larger stalks, retaining much moisture after the leaves and smaller stalks have become dry, offer a suitable soil for molds, and it is this quality

which apparently contributes largely to the hazard associated with this otherwise excellent form of roughage.

The identity of the molds responsible and the nature of the toxic substances to which they give rise have not been definitely established, although a species of *Aspergillus* has been isolated which produces in rabbits a disease closely resembling the one encountered in cattle.

The intoxication apparently produced by spoiled sweet clover hay appears to be accumulative as its effects do not become manifest until the feeding has been continued for at least two weeks. The specific action of the intoxicating agent brings about a material reduction of the clotting power of the blood, accompanied or not by changes of the capillary walls. As a result, the animals bleed within their own skins. When subjected to castration, dehorning or other surgical procedures, animals are apt to succumb to hemorrhages if spoiled sweet clover hay formed a part of their ration for a certain length of time.

The action of the saprophytic factors in food spoilage always results in the reduction of the feeding value of the material involved. In addition, there is good reason to give weight to the possibility of its having acquired toxic properties. For this reason, spoiled food should be rejected altogether, or if use must be made of it, it should be fed in moderate quantities, and well mixed with foodstuffs of normal quality.

Great caution should be exercised in the feeding of moldy food to horses and sheep, which appear to be much more susceptible to damage than cattle. The latter have been observed to feed with impunity on moldy food which killed horses with a marked degree of regularity.

In the prevention of poisoning by spoiled sweet clover hay, both its preparation and the method of its use must be given consideration, and those details may likewise be applied to other forage plants which are subject to spoilage.

By heavy seeding, a thick growth or "stand" may be secured, and as a result the stalks of the plants will remain thin and slender and can be more thoroughly desiccated in the process of hay making. The clover should be cut before the plant forms its flower buds, and care should be taken not to gather the hay when wet. The addition of about 50 pounds of common salt to the ton of hay, when stacking is in progress, has been recommended, and during storage the hay should be protected against moisture.

The coarser types of clover should not be used for ensilage as

this prevents close packing in the silo, and it is advisable to exclude air from the ensilage as much as possible.

If spoiled or moldy sweet clover hay is to be used for roughage in cattle feeding, it will be safer to offer it to older animals than to the younger ones. If at all possible, the use of such hay should not be continued for more than two weeks at a time. The animals should be fed on some other roughage for a similar period, after which the sweet clover hay can again be used for a two-week period. Animals having been fed on sweet clover hay should not be subjected to surgical operations until they have been fed on some other form of roughage for at least two weeks.

Of a major importance in the prophylaxis of whatever damage or danger which may be associated with the feeding of spoiled food is the method of harvesting or storing which assures the highest degree of dryness. Moisture is the all-important factor in the deterioration of hay and grain during the storage. In the case of ensilage, the defective packing of the material into the silo and the use of the coarser and undivided forage plants may lead to spoilage owing to the presence of air in the mass. Moldy food may be rendered less objectionable by exposure to the sun, airing, drying, shaking, or by passing it through separators and other grain-cleaning machinery. The use of the grain separator is particularly indicated for the removal of ergot from hay.

Animal Factors.—In veterinary literature a number of reports are to be found which indicate that disturbances in the health of animals may have been caused by various forms of animal life by which the food was infested. Most of these reports refer to instances of a considerable number of insects or other forms being masticated or ingested with the food, but the evidence presented with reference to their relation to the actual harm produced is not always convincing. In the absence of definite proof supplied by experimentally controlled observations, the substance of such reports requires to be accepted with caution.

The circumstantial evidence bearing on the subject, however, cannot always be dismissed, and it cannot be denied that the vesicant substances peculiar to many insect species, such as *Lytta vesicatoria*, *Mylabris phalerata*, and others, may cause injury to the alimentary mucosa when they infest the foodstuffs in considerable numbers.

The caterpillars of *Porthesia chrysorrhea* and *Bombyx processionalis* and their hairs are mentioned as causes of stomatitis in animals partaking of food in which these insects were present in

abundance. A similar result has apparently been observed when forage plants heavily infested with representatives of the genus *Aphis* were consumed by animals. A vesicating action is attributed to the secretions of *Blaps mortisaga,* with which the foliage was contaminated.

Rose chafers (*Macrodactylus subspinosus*) consumed in quantity by young chicks and ducks have been associated with their deaths, a cardiac poison being regarded as the immediate cause of the mischief.

Stomatitis, gastritis, enteritis, hematuria, and even forms of paresis have been traced to food in which the caterpillars of certain species of *Pieris* were present in conspicuous numbers.

Although the part played by insects and other forms of animal life as direct causes of tissue change or intoxication when taken in with the food may often be more apparent than real, there can be no doubt that the destruction of foodstuffs by agents of animal origin is not to be regarded lightly, and this quite independent of whatever may result from the consumption of the pests themselves. Foodstuffs infested are always less palatable and less nutritious; when, as the extreme results, the hay or grain has been reduced to a mass of vegetable débris and insect extrement, its nutrient value will have entirely disappeared.

Many animal forms are involved in the destruction of foodstuffs, some of the more conspicuous ones being: *Tenebrio obscurus, Tenebrio molitor, Pyralis farinalis, Atropos divinitoria, Calandra granaria, Calandra oryza, Ephistia kuenniella, Tenebroides mauretanicus, Lepisma sacharina, Silvanus surinamiensis, Tinea granella, Tribolium confusum, Sitotraga cerealella, Tylenchus scandens, Tylenchus dipsaci, Tyroglyphus americanus, Tyroglyphus farinae, Acarus plumiger, Acarus farinae, Amobium paniceum, Plodia interpunctella, Celama sorghilla.*

In abating the nuisance arising from the infestation of foods by insect pests, many of the methods recommended for the prevention of damage by mycotic agents can be used. Frequent agitation and handling of grain and hay, and storing in clean, cool and dry places are measures of value. Sound construction of granaries and their cleanliness are likewise of importance. In certain cases, grain-cleaning machinery can be used to advantage.

Poisonous Plants.—The occurrence of poisonous plants, either cultivated for ornamental or medicinal purposes, or growing wild as noxious weeds in meadows or grazing lands, not uncommonly requires

the attention of livestock sanitarians as well as of the toxicologist. In the regions where an ages old agriculture has subdued the wild flora and where a refined type of animal husbandry has reduced the hazard connected with poisonous plants to the status of occasional accidents, the problem may be a minor one which can be solved by ordinary prudence. Where, on the other hand, stock growing is carried on in areas like the higher prairie ranges of the North American continent and the African veld, the losses occasioned by toxic vegetation may be so great as to constitute a problem of preponderating importance.

The plants recognized to be poisonous are indeed very numerous, and the ones suspected of being poisonous are still more so. The toxicity of many plants does not appear to be a constant one, and the danger incurred by animals eating poisonous vegetation is also subject to variations in degree, depending on conditions associated with themselves.

Veterinary pharmacological and toxicological literature as well as descriptions of a purely botanical nature abound with references to these more special aspects of the subject, and to these the student must be directed for more fundamental information, inasmuch as the great number of plants involved does not permit an adequate description within the scope of this work.

The plants which appear to be responsible for the preponderating number of intoxications in livestock are species of the following genera: *Aconitum, Agrostemma, Asclepias, Astragalus, Atropa, Azulae, Buxus, Cicuta, Colchicum, Conium, Cotyledon, Crotalaria, Cynoctonium, Cytisus, Datura, Delphinium, Dichapetalum, Digitalis, Equisetum, Eupatorium, Helenium, Helleborus, Homeria, Hyoscyamus, Isocoma, Lathyrus, Ledium, Lessertia, Lencothoe, Lolium, Lupinus, Matricaria, Melia, Meliga, Menziesia, Mercuralis, Nerium, Nicotiana, Oenanthe, Ornithoglossum, Oxytropis, Papaver, Prunus, Pteris, Ranunculus, Rhododendron, Senecio, Taxus, Tribulus, Urginea, Vangueria, Veratrum, Xanthium, Zygadenus.*

Even in the most intensely cultivated sections the number of animals actually poisoned may still be a large one. Waste places, mountain slopes, canyons, swamps, river banks, roadsides and wooded patches, where systematic weed extermination is not possible, continue to serve as sanctuaries in which poisonous plants can maintain themselves without challenge. Furthermore, the practice of stable feeding and ultra-domestication are, no doubt, instrumental in a gradual

obliteration of the inherent instinctive ability of the herbivora to differentiate between poisonous and wholesome plants.

The careless disposal of the offal of flower gardens, of the trimmings of ornamental shrubbery, and the accidental presence of animals in enclosures where toxic plants are cultivated, may likewise supply the occasion for accidents.

Most of the losses due to poisonous plants occur on the open ranges where livestock must maintain itself under conditions of semi-domestication or in a more or less wild state. There animal husbandry must run the gauntlet of all the vicissitudes by which nature opposes the invasion of its pristine domain, and as the domesticated species concerned have not yet acquired, or have lost, the instincts which impel them to avoid what is dangerous among the vegetation on which they are compelled to subsist, the risk incurred by them is often a conspicuous one. For this reason, livestock accustomed to a range dangerous on account of certain species of plants are less apt to succumb than animals recently introduced and foreign to their new surroundings.

Under certain circumstances, however, even animals bred on the dangerous ground may become victims equally well as the newcomers. These circumstances are all founded on one factor, and that is hunger, the pressing desire for food which annuls all caution, however instinctive and well acquired it may be.

When animals, hungry after long drives or railway journeys, are set free on a grazing ground where poisonous plants abound, the supreme passion for food permits no selection of the forage to be consumed, and fit, unfit or dangerous morsels are greedily swallowed without discrimination.

The urgent desire for food commonly leads to poisoning during the spring when forage plants are scarce or during seasons of drouth when the range grasses have withered and when many toxic weeds are yet green and attractive to half-starved animals. The same factor operates when the ranges are over-stocked and the consequent scarcity of herbage forces animals to eat any plant which may happen to be available.

Wherever animals are apt to concentrate on the range, the risk of poisoning becomes greater as the supply of grass grows less. This is especially observed around watering places and the permanent bedding grounds of sheep, and when animals closely herded are rapidly driven over established trails or fixed driveways.

As a rule, the poisonous plants are not eaten by choice; accord-

ingly, there is a well-established relation between food shortage and the mortality induced by toxic vegetation. On the worst-depleted ranges the desirable food plants suffer the most and become backward in their growth, whereas the noxious weeds retain their vigor and become conspicuous in advance of the regular forage of a new growing season. Under such conditions, early grazing may bring disastrous results.

Preventive Measures.—The prevention of plant poisoning under conditions of complete domestication which render possible a perfect control of the nature of the food offered is, to a large extent, a matter of care and sound management. Poisonous species commonly grown for ornamental purposes should not be tolerated in places to which livestock has access. Offal and trimmings of parks and gardens are to be adequately disposed of whenever there is the least doubt in regard to their character, and, as a rule, prudence demands that such material should never be supplied to animals as food.

Toxic species should not be allowed to grow in pastures and other enclosures to be occupied by livestock, if it is at all possible to dispose of them by the means commonly employed in weed eradication. For instance, the seedlings of cocklebur (*Xanthium*) must be destroyed in areas set aside for young swine, and care is required in the removal of water hemlock (*Cicuta*) from low places to which cattle and other animals have access.

In cultivated regions, the prevention of plant poisoning is largely dependent on the successful eradication of noxious weeds in general. From the standpoint of sound agriculture as well as of hygiene, such conspicuous nurseries for weeds as roadsides, waste places, swampy areas, edges of ditches and streams, etc., may well be included in the field of operation.

In many such places the control of poisonous meadow plants is often a matter of land drainage, for such species are commonly more apt to thrive on wet or swampy land. As an alternative, especially dangerous ground may be fenced off.

In the case of annual plants the use of scythe or mowing machine before they can produce seed is a most useful method of eradication. Hand pulling or digging or grubbing is indicated when perennials are to be eliminated. When such plants occur on limited areas, they may be smothered by covering the ground with a thick layer of straw or stable manure; in some instances, they may be crowded out by the introduction of cultivated plants of luxurious growth.

Most of the measures of weed control which can be profitably em-

ployed in cultivated regions cannot be applied under range conditions. The great areas of land involved, the tenacity of the undesirable species in their natural habitat, scarcity of personnel, and economic considerations tend to make the poison-plant problem of range, veld or bush an exceedingly difficult one. Here and there eradication by digging or grubbing may be accomplished, and on limited areas, repeated mowing will establish safety. Tall larkspur (*Delphinium*), which often grows in circumscribed patches, may be successfully and economically destroyed by grubbing; the same method may be used against loco weeds (*Astragalus-Oxytropis*) on land under fence. Water hemlock (*Cicuta*) growing on soft ground can be readily pulled up, and when it occurs in small areas the effort may be a good investment.

On the whole, such radical measures will but slightly affect the total mortality of livestock on the open ranges, and although they should be employed wherever feasible, means directed more toward the attainable reduction of losses than to their absolute prevention must find application.

Such measures are largely associated with the management of the range as well as with the method by which the animals are handled. They require of ranch owner or manager a more or less thorough knowledge of the nature and distribution of dangerous plants on the range he occupies. Such knowledge may enable him to select the areas which are safest for animals new to the range, for these animals, on account of the greater likelihood of their becoming poisoned, require a more careful handling than livestock accustomed to their grazing ground.

Recourse to "sanctuary" pastures may be had in cases in which the poisonous vegetation is eaten only at certain stages of its growth or when the toxicity is a temporary one. A sanctuary pasture is one from which the dangerous plants have been scrupulously removed. Such a grazing ground is reserved for livestock during the relatively brief period during which their occupancy of the free range may be hazardous.

The difference in the susceptibility of the various animal species may be utilized to advantage in the prevention of losses. Sneezeweed (*Helenium*) poisonous to sheep offers no danger to horses and cattle. Cattle are very apt to become poisoned by low larkspur (*Delphinium*), which is not dangerous for sheep and horses. Sheep herded closely on low larkspur areas may to such an extent destroy the plants as to bring about a period of comparative safety for cattle using the same

grazing ground. Ranges dangerous to sheep on account of death camas (*Zygadenus*) are relatively safe for horses and cattle, and to a considerable extent this is true of areas where lupines (*Lupinus*) are apt to become a causative factor in sheep losses. With a definite knowledge of the distribution of the species mentioned the ranges may be allotted to the kind of animals less liable to meet disaster.

The fact that the toxicity of certain plants frequently varies with their stage of growth renders them more dangerous at certain times of the year and may be taken advantage of in the direction of grazing operations. Death camas (*Zygadenus*), which may be fatal to sheep early in the grazing season, withers and disappears soon after blossoming, so that the range involved can be safely occupied by sheep after that time.

Lupines (*Lupinus*) are most to be feared late in summer and during autumn when the most toxic part of the plant, the seed, is available, so that a lupine range should be avoided for the more susceptible animals. The low larkspurs are factors in cattle poisoning early in the season, but except in regions of high altitude they will have disappeared by July. This seasonal influence is less marked for tall larkspur, although these plants also lose much of their toxicity after blossoming.

The most potent factor in the prevention of poisoning by plants is an abundance of desirable food. The lack of food, in more than one way, leads to livestock losses through intoxication. It is responsible for the hazard from poisoning when the range is overstocked and the scarcity of food forces animals to satisfy their craving for nourishment by eating plants which otherwise they would avoid. Regard for the carrying capacity of the range when it is used for grazing is not only hygienically sound, but it also tends to preserve the grazing ground for continued occupancy. Badly overgrazed land should be vacated for a time in order to permit its recuperation and the strengthening of its food plants.

Scarcity of food may not always be the result of a general overstocking of the range, or the calamity of drouth. It may come about by the faulty handling of herds or flocks. The more or less constant concentration of animals on the same ground may so deplete the vegetation that they will be tempted to eat whatever poisonous plant may be within their reach. For this reason, fixed routes or driveways should be avoided, and instead of establishing a more or less permanent bedding ground for sheep, it is much safer to select a new one every night if at all possible.

If sheep or cattle have to be driven over ground dangerous to them on account of poisonous plants, they should be well fed and then driven slowly and in open formation. Hungry animals driven in compact masses will eagerly eat any vegetation which is left by those in the vanguard of the moving herd.

A plentiful supply of food cannot prevent all losses from plant poisoning on the range, but it constitutes a powerful defense. Whenever possible, range management should be so directed that in time of scarcity the grazing may be supplemented by hay feeding. If by the use of such a supplementary food, the food grasses on the range could be permitted to attain a vigorous growth before being extensively grazed upon, the hazard from poisoning would be materially reduced.

Foreign Substances in Food. *Extraneous Impurities.*—Aside from the many biologic forms which, by their presence in the food, may affect its quality, the addition of other substances or objects is not always to be regarded with indifference. During the processes of production and storage, extraneous materials may become mixed with the food either unavoidably or through lack of care in the course of handling. They are of unlimited variety, ranging between inert substances and those that are decidedly harmful. The harmful ones belong to two classes, namely, those which may produce mechanical damage to animals and those which are endowed with toxic properties.

Among the former we recognize such substances as sand, gravel and metallic objects such as nails, pieces of wire, and the broken parts of grinding, threshing or harvesting machinery. Sand taken in by animals grazing in sandy pastures not only may bring about excessive wear of the teeth, but has been observed to lead to marked intestinal disturbances. Hard gravel or pieces of metal may inflict damage to the molars of horses, and pointed objects may penetrate the soft parts of the alimentary tract and bring about such ultimate results as traumatic pericarditis of the bovines.

The awns and beards of graminaceous plants and the spines and thorns of many others may cause injury to the mucosa of mouth, pharynx and esophagus, when taken in with the food. The beards of such plants as wild barley (*Hordeum jubatum, Hordeum murinum*) which frequently form a conspicuous portion of forage or hay are apt to penetrate deeply into the soft parts of the mouth and into the tongue and to give rise to extensive infectious processes. The abrasions caused by the spikelets of barley, rye, spelt and other

grains, as well as their penetration into the tissues, are notorious factors in the etiology of actinomycosis.

The poisoning of animals as a result of toxic substances present in the food has been frequently recorded in veterinary literature. In many of the cases reported, salts of the heavy metals have played a part. Left-over seed grains treated with copper sulphate as a fungicide and fed to animals may become responsible for poisoning, and foliage sprayed with a suspension of Paris green has caused the death of animals which partook of it. Fowls feeding on caterpillars and other forms of insect life killed by arsenite of lead have died as a result. Sheep treated in arsenical dips have become poisoned when they were given the opportunity to eat the grass upon which the fluid dripping from their fleeces had been deposited.

The habit of farmers of adding quasi-medicinal substances to the ration of swine has resulted in the death of such animals when the "tonic" or "conditioner" contained arsenic, and the adulteration of foodstuffs with sweepings and other wastes must also be looked upon as a source of danger.

The feeding of horses with oats treated with strychnine for the eradication of gophers has been a common and very disastrous form of carelessness on western farms.

The foodstuffs transported in railway cars or ships which were not adequately cleaned after being used for shipments of poisonous chemicals may become sufficiently contaminated to be dangerous to livestock. Feeding utensils newly painted with lead paint may become responsible for intoxication, and food of acid reaction (sour milk, fermenting grains) stored in copper receptacles or enameled vessels may lead to copper or lead poisoning of animals which consume them.

Poisoning has also resulted from the feeding of turnips grown on land subject to overflow of lead-bearing streams, the soil attached to the roots containing enough lead to cause disaster.

The presence of sulphurous acid, arsenic, lead or zinc in the gases and fumes of smelters has been held responsible for many losses of livestock in their vicinity. Improvement in the technique of smelting operations has reduced these losses materially in later years. The introduction of condensers and sublimation chambers, the cooling of the gases, the reduction of the velocity with which they are ejected into the atmosphere as well as increases in the height of smokestacks have been especially instrumental in the reduction of this danger.

The hazard of livestock connected with smelting operations may

be further reduced if the animals are turned into the pastures only after the forage has been washed clean by rain or if the hay produced on the land is thoroughly freed from dust. Roots and tubers growing on such land must be washed clean before being offered to livestock.

In the prevention of damage by foods rendered undesirable or toxic by an admixture of extraneous substances, care in preparation and storage is obviously the most dependable measure.

Food and Infection.—The food serves as a vehicle for a considerable number of pathogenic micro- as well as macro-parasites. The alimentary canal is the port of entrance for many specific infections, and food as well as drinking water plays a prominent part in disease transmission. As a rule, the microbic factors of disease occurring in food can be traced to contamination by animal ejecta or other materials of animal origin. Certain pathogenic molds or fungi, however, furnish an exception.

A number of these biologic forms occurring in nature as saprophytes are capable of becoming parasitic in the animal body. Several species of *Mucor* and *Aspergillus* have been identified as producers of inflammatory reactions either in such peripheral parts as the cornea, the skin and the external auditory canal, or of such internal organs as the lungs, the air sacs and the serous membranes. Mycotic infections are most commonly noted in birds, but they have also been observed in horses, cattle, lambs, rabbits and dogs. They can frequently be attributed to the use of moldy food which supplies the means of contact with the molds and their spores in the same manner as intoxications by spoiled food may come about. They can be similarly guarded against.

In the etiology of actinomycosis, the food is the principal factor. The ray fungus (*Actinomyces*) vegetates on graminaceous plants, and when attached to the awns and spikelets of grass and grains (barley, spelt, emmer) penetrating the mucosa of the mouth, tongue and pharynx, it finds its way into the deeper tissues, where it is able to assume a parasitic rôle. The foodstuffs mentioned should either be finely ground or be subjected to sterilization by steaming or boiling when the danger of actinomycotic infection is to be especially guarded against.

The contamination of the food by the pathogenic bacteria or by gross parasites may come about in various ways. In stables where it is difficult to prevent the various body wastes and discharges from polluting the food or in which animals are apt to eat the bedding material and litter, infected food is often responsible for the trans-

mission of tuberculosis, glanders, strangles, abortion disease, cattle plague, foot and mouth disease, calf diphtheria, colibacillosis and other specific infections.

Forage plants may transmit such diseases as anthrax and blackleg. The spores of the causative microbes occurring in the soil and adhering to the food plants readily find their way into the body of grazing animals. The foliage soiled with the infective contents of the uterus of an aborting animal constitutes a positive danger to pregnant animals at pasture, and this danger is further increased when the microbes concerned are spread over large areas after a heavy rainfall.

Anthrax spores deposited on pasture lands with the silt of streams receiving the wastes of tanneries, and other establishments using raw materials of animal origin, have been held responsible for serious outbreaks of disease among grazing animals.

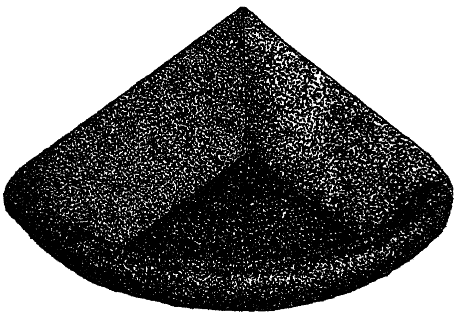

FIG. 24.—Cast iron feed box for horses. (After Hunt-Helm, Ferris Co.).

The feeding habits of swine and domesticated birds kept confined in yards when the soil has become heavily charged with fecal matter cause these types of livestock to become particularly exposed to such diseases as paratyphoid infections, fowl cholera, avian tuberculosis, fowl typhoid, coccidiosis, blackhead and the infestation by intestinal and other helminths.

The fecal contamination of food is commonly rendered possible by the inadequate construction of troughs, mangers and other containers. The transmission of avian tuberculosis to swine and to fowls is commonly the result of the consumption of food so polluted.

Foodstuffs are exposed to dangerous contaminations when conveyed in ships or railway cars infected by a previous shipment or cargo of hides or similar materials taken from animals suffering from such diseases as anthrax, foot and mouth disease, and others.

The eggs or larvae of many gross parasites clinging to pasture plants can be transmitted to new hosts during grazing operations.

It is obvious that foodstuffs of animal origin occupy a prominent

position among the factors which may become responsible for the transmission of disease. Milk, especially, has frequently been identified as an infection vehicle in connection with foot and mouth disease, tuberculosis, colibacillosis, mastitis, enteritis, anthrax, etc. The streptococci, staphylococci and representatives of the coli group associated with udder infections may lead to digestive disturbances and even enteritis in calves fed with the infected milk. Similar results may be observed after the milk becomes contaminated with fecal matter of animals suffering from infectious processes in the alimentary canal and with post-parturient morbid conditions of the uterus.

The milk of tuberculous cows has conspicuously aided in the dissemination of the disease. The skimmed milk of creameries or butter factories and the whey of cheese factories sold for calf feeding have caused tuberculosis infection to penetrate deeply into the bovine and porcine population of many sections.

Meat also may serve as a vehicle of infection. Kitchen offal, containing meat scraps, fed to swine, is held accountable for hog-cholera outbreaks which could not be otherwise explained. The viscera of fowls dressed for table use may transmit tuberculosis to poultry and to swine, and other specific avian diseases can be readily disseminated by the same material when disposed of in a manner affording opportunity for birds to consume it.

The reckless feeding of carcasses to swine without the least challenge as to death causes and the use of horse meat as food for menagerie animals (glanders-anthrax) has been known to bring disastrous results.

All tapeworms of which the life histories are known are transmitted with the food, and sheep heads containing the cysts of the gid tapeworm left for dogs to consume have contributed materially to maintaining turn-sickness as a perennial source of worry to flock owners. Trichinosis is always a food-borne disease and will continue to be a public-health problem as long as the meat of one animal can be devoured by another.

Preventive Measures.—A not inconsiderable part of the task of the hygiene of feeding must be devoted to safeguarding the food supply and preventing it from becoming a vehicle for pathogenic microbes or for the eggs or larvae of the gross parasites.

Foremost in sanitary practice is the elimination of primary infection sources, the infected or the infested animal. To this the safeguarding of the food supply, even if its value cannot be overestimated, must always remain a matter of secondary concern. The

importance of this is particularly associated with such facts as that primary infection sources are not always promptly recognized, that pathogenic biologic factors are more or less ubiquitous and that efforts tending to prevent their access to food are in a measure the first line of defense against a multiplication of infection sources.

Cleanliness pertaining to the storage of foodstuffs and to the disposal of body wastes is a prerequisite to sanitary safety. Feeding practices and equipment designed to remove the possibility of fecal contamination are fundamental in the control of many diseases.

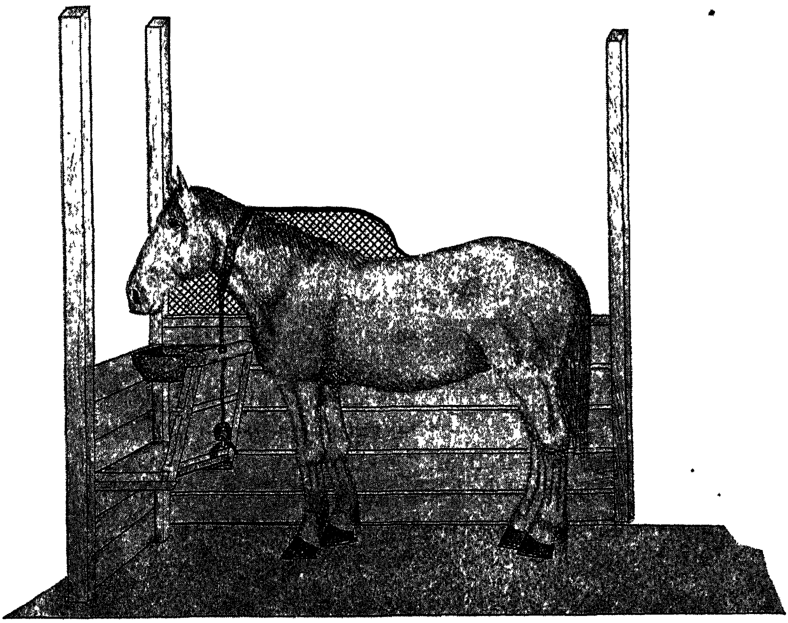

Fig. 25.—Manger and feed box for horses.

Foodstuffs conveyed in carriers used for the transportation of such raw materials as hides, hair, wool, green bones and the like are to be regarded with suspicion and should be rejected unless such carriers were subjected to adequate disinfection or sterilization prior to loading.

Pastures unsafe on account of anthrax, such as the "champs maudits" of France, are rightly to be avoided for livestock. Overflow lands apt to become contaminated by the wastes of industries using materials of animal origin should not be used for the produc-

tion of food for livestock, or else the manufacturing process must be made to include efforts rendering the spread of infection impossible by technical improvements.

In the use of foodstuffs of animal origin, special precautions are always required. The source of such materials should either be known by special inquiry (tuberculin test of milk cows) to be infection-free or the foodstuffs should be subjected to sterilization or pasteurization prior to feeding.

Such measures are to be especially applied to milk, the most common vehicle for the transportation of tuberculosis and a frequent one for such infections as colibacillosis, foot and mouth disease and others. The skimmed milk and whey sold by manufacturing establishments using the raw milk of many herds should not be used for the feeding of livestock without having been previously exposed to a temperature sufficiently high to destroy pathogenic microbes. This can be most adequately done in the factories, where suitable heating facilities are more apt to be available than on farms and where the operations can be most readily controlled. Countries or states which prescribe such measures by legislative enactment display indeed a high order of sanitary wisdom.

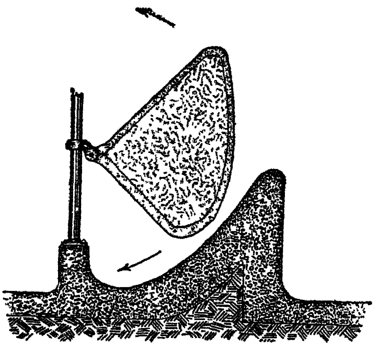

FIG. 26.—Concrete feed trough for cattle with metal partition.

Tubercle bacilli are killed when heated to:

131° F. for 4 hours
140° F. for 1 hour
149° F. for ¼ hour
158° F. for 10 minutes
176° F. for 5 minutes
194° F. for 2 minutes
203° F. for 1 minute

provided that the milk or milk product is contained in a covered vessel and with an equal distribution of the temperatures mentioned.

On farms where the temperatures cannot always be readily controlled, sterilization by boiling is to be recommended. New-born calves frequently tolerate boiled milk badly and in such animals it

may become the cause of severe or even fatal digestive disturbances. Hence it is advisable that milk so treated should not be fed before the second or third day after birth. The boiling of the milk need not to be unduly prolonged, as an exposure to boiling heat in a covered vessel for three or four minutes constitutes an adequate safeguard against most infections. It is true that heating destroys milk enzymes which are beneficial in their action, but in the face of any infection danger, this consideration is not sufficient to reject this process of sterilization. If, under the pretext of preserving the desirable zymases, a milk is fed charged with microbic pathogens, the danger of harming the young animals by infection or intoxication far exceeds that associated with a milk deprived of its desirable ferments.

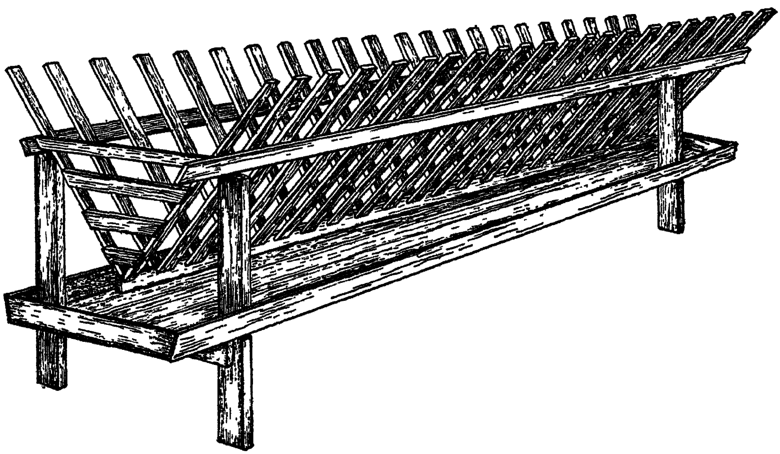

Fig. 27.—Feed rack for cattle for yard feeding.

When meat, slaughter-house offal and similar products of unknown or questionable origin are to be fed to animals, the sterilization by boiling is always indicated as a matter of sanitary prudence.

Feeding Practices and Equipment.—The conditions imposed by domestication and economic utilization affect the alimentary process of the animal body in a most profound manner. In the wild or predomesticated state, the food requirements for maintenance and growth, for reproduction, for muscular energy, and other functions upon which the preservation of the individual and species depends, differ materially from those peculiar to the domesticated state, in which the animal body is called upon to yield an additional output of energy and substance. This extra output can be secured only by

the utilization of a greater quantity of nutrients which places upon alimentary and metabolic functions burdens for which the organic equipment is not always adequately prepared.

In a measure, the requirements imposed by domestication are abnormal. They call for a more or less violation of physiologic laws, which is apt to be followed by penalties often expressed in morbid conditions. Two factors, however, tend to prevent violation or to attenuate the penalties likely to be imposed. One is the development of a degree of adaption of the alimentary and metabolic processes to the requirements of domestication, and the other is the hygiene of

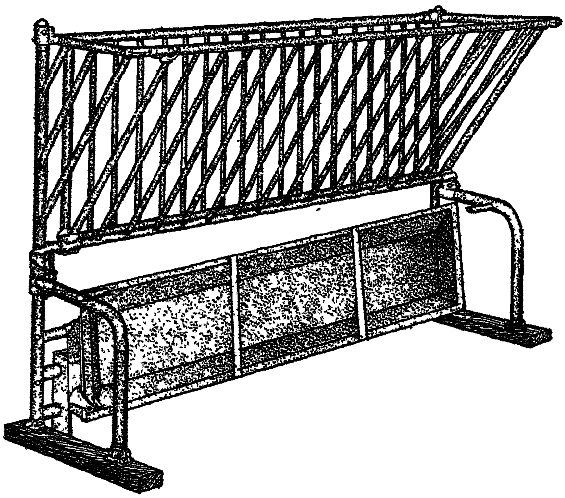

FIG. 28.—Feed rack for sheep. (After Jamesway.)

nutrition, which in addition is designed to eliminate the infection hazard peculiar to an established animal husbandry.

Feeding Practices.—Aside from the nutritional needs of the body, the economic phases of feeding and the hygienic aspects of food quality, the manner in which the food is to be supplied is not without importance.

The feeding of horses with grain always requires supervision and caution. The relatively small equine stomach seems to invite acute overfeeding and the gastric disturbances incidental thereto. Foodstuffs apt to swell after entrance into the stomach must be fed cautiously and in relatively small quantity. Preference should always be given to foods which require thorough mastication and insalivation as this effectively prevents a hasty over-filling of the stomach.

Abrupt changes in quantity and variety of food should be avoided. The simultaneous ingestion of roughage and concentrates is advisable because it tends to distend stomach and intestines in a proper manner to promote a favorable action of the digestive juices and to reduce the momentary burden placed upon the digestive function.

Like most ruminants, cattle are capable of utilizing a very voluminous diet and of prospering on foods rather rich in water. When on the other hand such animals are producers of muscular energy (work oxen), a more concentrated food is required. In this instance, also, sudden changes in variety and quantity of foodstuffs must be avoided, and acute overfeeding is always to be guarded against.

Sheep require a rather fine, dry food, and roughage and concentrates are best fed separately. In feeding yards and similar close

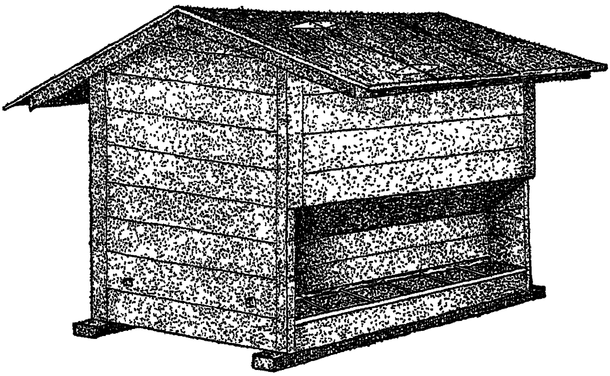

FIG. 29.—Self-feeder for swine.

quarters the hay should be supplied daily, for apparently this type of livestock prefers its food fresh rather than left over by other members of the flock. If a small number of sheep are fed, there is no objection to supplying the roughage in racks large enough to hold a quantity sufficient for several days. The feeding equipment should always be adequate for all animals to eat at one time.

An easily digested food with a minimum of crude fiber is advantageous to swine, as they masticate their morsels rather incompletely and the ingested mass passes quickly through their relatively short alimentary canal. By such preparations as crushing, grinding, steaming and soaking the foodstuffs can be rendered more accessible to digestive action.

In the wild state, animals feed at will and leisurely, but under

the conditions imposed by domestication, this is not always possible. This natural feeding is approached in the use of self feeders which apparently have come into general use for swine, poultry and certain types of cattle (beef production). Animals used for motor purposes, such as horses and work oxen, cannot be fed in that manner; in the feeding of milch cows at least part of the food is usually supplied periodically.

Although practical considerations and convenience largely determine the number of meals per day, preference must be given to the greater number of feeding periods so far as concentrates are concerned. In this connection it is always important not to feed too

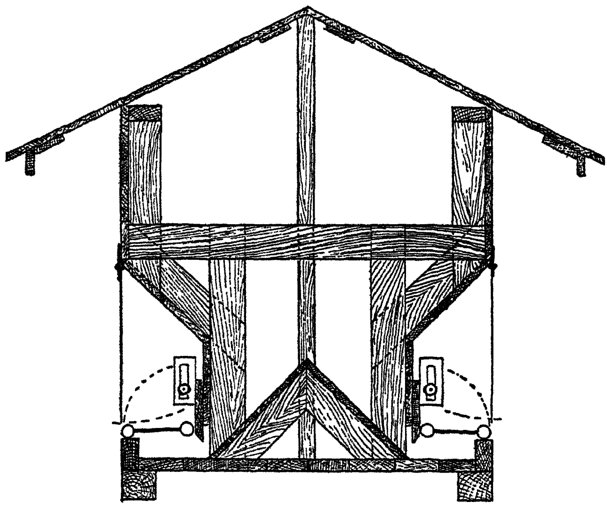

FIG. 30.—Cross section of self-feeder for swine.

large a ration at one time, and from a hygienic standpoint the frequent, but none too bulky, meals of concentrates must be given preference, and the animals must be permitted adequate time for the feeding periods.

Whereas dogs can get along with one meal per day, horses, cattle, sheep, swine, and poultry must be fed their grain ration two to four times per day. As a general rule, the less frequently the animals are fed, the greater should be the caution when concentrates are fed. On the other hand, there is advantage in keeping roughage available for animals all the time.

Though the time of feeding is of minor importance, it is quite essential that the rationing be done with regularity. It is preferable

to feed dairy cows after milking, because evidence shows that if they are fed before milking the milk yield is less, and consideration must also be given to the fact that the feeding of roughage before milking so increases the amount of dust in the stable atmosphere that it is quite sure to increase the bacterial count of the milk.

Horses returning from work, hot and tired, should not receive their grain ration until after a sufficient period of repose. A certain amount of hay can, however, be allowed and may even be advantageous by its quieting effect on the animals.

Cleanliness should mark all feeding practices. Remnants of soured or spoiled foodstuffs should not be permitted to become mixed with the next ration, and in view of the fact that the food so frequently serves as a vehicle to infection, all risks of fecal and other contamination should be painstakingly avoided.

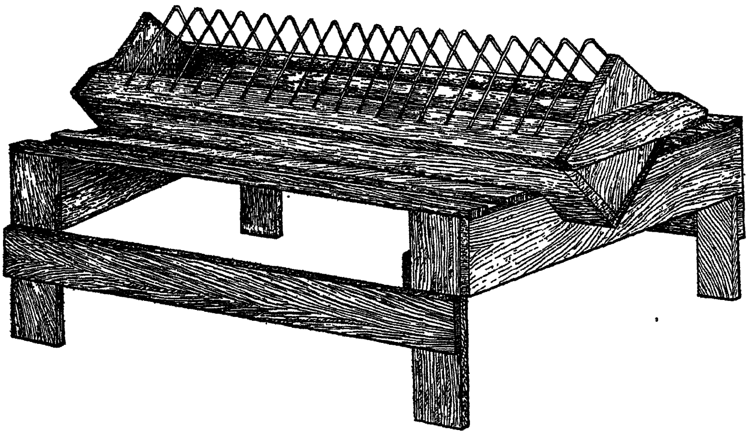

FIG. 31.—Feeding trough for poultry.

Equipment.—The quality of the equipment used for the storage of foodstuffs, as well as that of the utensils or fixtures in which the food is offered to animals, is an important factor in the hygiene of feeding.

Storage spaces should be so constructed that a high degree of cleanliness can be secured and so placed that animals cannot gain access to them. Vermin-proof, concrete construction, would, of course, be the ideal equipment, but economic considerations often stand in the way of making this available. Nevertheless, an attempt should be made by the use of sheet metal so to construct oat bins and

other receptacles for grains as to keep out such marauders as rats and mice.

Dryness is of prime importance for all spaces in which food is stored, and a certain degree of ventilation of bins and granaries is indispensable to the wholesomeness and preservation of the materials stored.

Root cellars must be frost proof and yet should be so placed and

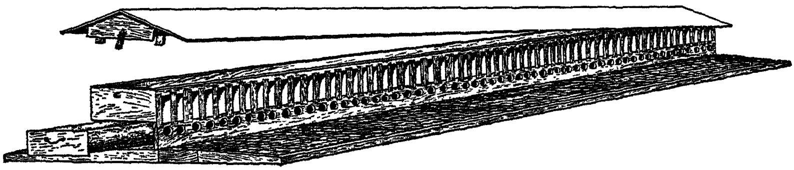

FIG. 32.—Self-feeder for poultry.

constructed as to prevent excessive heating of the contents. Proper ventilation of such cellars is highly essential.

Silos should be tightly built and so substantially constructed that there is no danger of the walls cracking.

Receptacles for the storage of such perishable foodstuffs as milk must be so made that thorough cleansing can be readily accomplished.

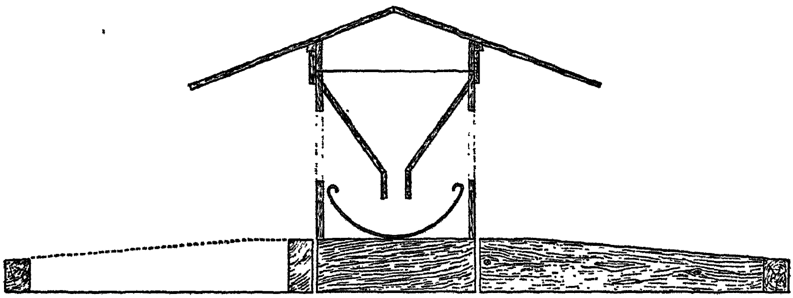

FIG. 33.—Cross section of self-feeder for poultry.

Heavily tinned metal is a suitable material and will resist the acid fluid within to a considerable extent.

All feeding utensils, fixed as well as movable, must be built or constructed with a view to cleanliness. Foul and souring food remnants accumulating in corners, seams, and crevices are not only objectionable from a sanitary point of view (food intoxication), but they likewise have a depressing influence on the appetite of most animals. Not only must it be possible to secure a maximum of cleanli-

ness, but when, in the face of infection danger, disinfection becomes necessary, there should be nothing in the construction to prevent it from being done in the most thorough manner.

The nature of the material used in construction to a marked degree determines the sanitary qualities of feeding utensils and equipment. Impervious material permitting a smooth finish of all surfaces is always preferable and especially so if it has the durability to withstand wear and tear without cracking or splintering.

Wood is still widely used for the construction of mangers, feed boxes, and hay racks, and probably will continue to find a wide application in spite of some manifest disadvantages. It is the least durable of the materials in general use, and wooden equipment is commonly damaged by the animals' biting and gnawing.

The porosity of wood and the presence of joints, seams, and sharp corners peculiar to wooden construction render cleaning difficult and disinfection often impossible. Cast-iron feed boxes with smooth surfaces and rounded corners more adequately meet the present-day hygienic requirements. Galvanized-iron feeding troughs and boxes are also excellent. They have the advantage of greater lightness as compared with cast iron, but are more readily damaged. Also, the ragged edges of a broken, galvanized-iron trough or feed box may become responsible for wounds and abrasions of the animals which are forced to eat from them.

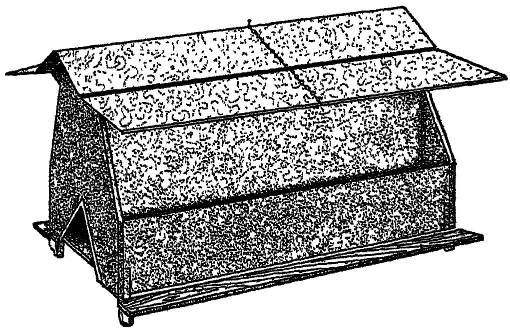

FIG. 34.—Self-feeder for poultry, designed to prevent waste. (After Bergmann.)

Wrought iron is frequently used for hay racks and permits a substantial and durable construction. The feed boxes of porcelain, cut stone, or stoneware sometimes seen in luxury stables are very excellent, but owing to their greater cost they are rarely used in establishments operated for profit.

The use of concrete permits a more economical construction. If sufficiently hard and smooth of surface this material meets all sanitary requirements. The permanently fixed feeding troughs or gutter (Fig. 26) of the better type of cow stable not only have become

widely popular with stable managers, but constitute an important advance in stable sanitation.

Movable concrete troughs for swine are also used. Aside from their great weight they offer no objectionable features, as long as they are of sufficient hardness to prevent their chipping by animals biting at them. Certain types of concrete, however, become slowly corroded when acid foods (sour milk and slops) are continually used in them.

In the construction of feeding utensils, attention must be paid to durability as well as to details which are conducive to cleanliness. Rounded corners and smooth surfaces are important features, and projecting parts are not permissible because the animals might injure themselves on them.

Feed boxes must be wide and roomy enough to permit the animals to masticate their food without the need of withdrawing their heads, a frequent cause of wastage. All feeding fixtures should be placed at a height neither high enough to cause discomfort nor so low that the animals might get their feet into them. Mangers and similar fixtures should be made to recede away from the animal from above downward in order to make room for the legs and to prevent injury to the more exposed synovial structures of the latter. Also, they should be built up from the stable floor, to prevent animals from getting their heads under them.

Detachable fixtures, if otherwise substantial in construction, can be more readily cleaned than the ones solidly fastened to other parts. Feeding boxes and troughs, with the exception of concrete feeding gutters for cattle, should always be removable.

If it can possibly be avoided, hay mangers and hay racks should not be placed too far overhead even if in many stables this is a constant feature. Hay racks placed too high force animals to assume uncomfortable positions while eating, and the falling dust not only may cause injury to the eyes, but also tends toward untidiness. Hay racks of wrought iron are preferable for horses, but the movable racks for sheep are best made of wood. All hay racks should have a manger below to prevent wastage and the soiling of the roughage by contact with the ground or with the stable floor. In the case of sheep, such an arrangement is further instrumental in keeping the fleece clean. For the feeding of pregnant ewes the placing of racks and mangers in a circle is an excellent arrangement to prevent crowding.

Troughs used for the feeding of grains to sheep should have a wide, flat bottom, as this promotes a more leisurely consumption of

the food. For the stable feeding of cattle, the concrete gutter-trough built as a part of the stable floor has many advantages, although individual mangers or troughs may be preferable when infection danger (tuberculosis) is a factor to be considered. Movable partitions used in connection with the concrete feeding gutters prevent unequal distribution of the rations and tend to retard infection spread.

Tilting galvanized feeding troughs are not without merit, but in a measure they do away with the structural simplicity conducive to cleanliness.

Feeding troughs for swine are best made of concrete, and galvanized or cast iron. They should be provided with iron guards in order to prevent the animals from lying down in them. Troughs for

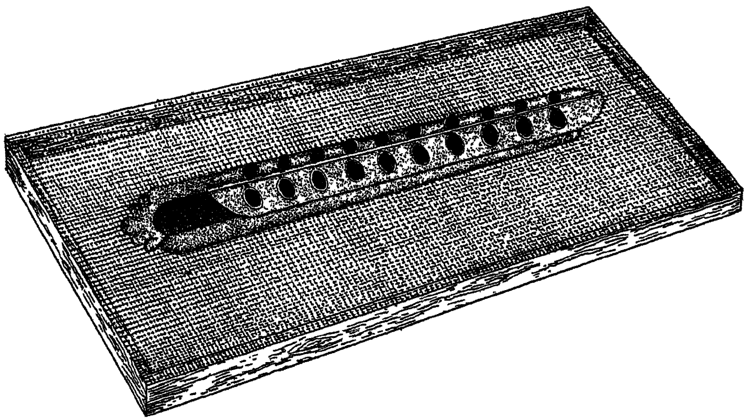

FIG. 35.—Food trough for chicks on wire screen.

the use of swine are preferably placed upon concrete feeding floors as a measure to prevent gross contaminations by soil and fecal matter. Feeding from the ground should always be avoided. Fixed troughs which form part of pens and stables are commonly placed in the front wall so that, by means of a valve suspended above, they can be made to communicate either with the inside or the outside of the enclosure.

Feeding utensils for poultry should be so placed and constructed as to reduce to a minimum the danger of pollution by soil or fecal matter. A suitable trough placed upon a low platform and provided with guards or heavy wire will meet most sanitary requirements. Hopper feeders, suitably placed and constructed on the principles of the self-feeder for cattle and swine, are quite excellent for the use

in poultry yards. They are in common use for fattening cattle and swine. Not only are they satisfactory from the standpoint of economic feeding, but they are also of a decided sanitary value.

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CHAPTER VII

RADIANT ENERGY

RADIANT energy, of which the sun is the chief source, is among the most potent of forces and influences which affect biologic existence. The sun's rays are the fountain head as well as the nurse of all life, and however different the metabolism of plants and animals may be, the energy supplied by solar radiation is a primary factor in the origin and maintenance of the various processes which culminate in life. Its influence must likewise be given consideration among those which help to determine the state of animal health and well-being.

Indispensable to life itself, radiant energy, on the other hand, may be directly damaging to protoplasm and indirectly to health itself. That its action is not uniform is due to the fact that it is not homologous in character, but consists of a complex of rays differing in quality and in action; the animal body, likewise, is composed of an uncountable number of units presenting the widest variation in their susceptibilities and of substances greatly differing in their affinities.

Whereas the unicellular forms of life are injured by the direct exposure of solar radiation, the somatic complex of the higher animals requires contact with the sun's rays even if most of the body cells are themselves inaccessible to their more direct action. The interaction between radiant energy and body cells, taking place within certain limits, flexible only to a degree, helps to bring about the optimum conditions under which the metabolism takes place. When those limits are exceeded, conditions arise which are opposed to the undisturbed functioning of the process upon which the state of health is dependent.

Solar Radiation.—The heat energy at the surface of the sun is transformed into energy of vibration of the ether, the hypothetical medium serving to explain the propagation of waves by which radiant energy is transmitted.

Radiant energy varies in wave length, being composed of rays each

having a definite length of wave by which its quality is largely determined. For practical purposes, it is sufficient to divide the rays composing solar radiance into heat rays, light rays and chemical rays.

Of these, the light rays are visible, the only ones capable of exciting the sensation of vision. They have wave lengths between 400 and 780 millimicrons. These limits are, however, not sharply defined, but with light of a given intensity they may vary in different individuals and with the degree of fatigue of the visual apparatus.

When the luminous rays, light, are separated by a prism, it can be shown that the prismatic spectrum contains heat as well as light rays, and that the heat spectrum extends far beyond the visible or light spectrum, of which the red rays, having the longer wave length, constitute one of the limits. In a similar manner it can be shown that

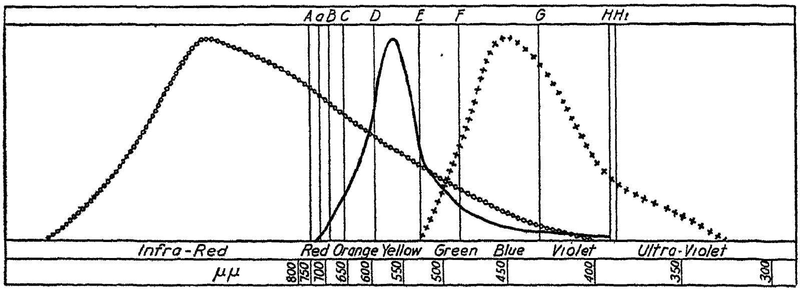

FIG. 36.—Approximate energy curves for calorific, luminous and chemical rays. (Solar radiation.)

the prismatic spectrum also contains rays capable of chemical action, and that the chemical rays extend beyond the luminous ones in the region of the violet on the other extreme of the visible spectrum.

Thus there are invisible rays at either extremity of the visible spectrum. Those of the greater wave length, beyond the red, known as infra-red rays, are purely heat rays; the shorter rays, beyond the violet of the spectrum, the ultra-violet rays, are endowed with chemical action only.

Within the visible spectrum the thermic rays diminish with the shortening of the wave length from the red toward the violet parts as the chemical energy increases in the same direction. Whereas the extreme red rays are almost wholly inactive chemically, the violet rays have practically no thermic qualities.

Hygienic Importance.—Although expediency has prompted the division of radiant energy in heat rays, light rays and chemical rays,

it is not possible to always attribute whatever influence they may have on animal life and well-being to any one particular wave length by which the various rays may be distinguished.

Similar to the occurrence of caloric and chemical rays in the visible spectrum, their influence on living matter may likewise be of a more or less complex nature, and even this influence is not always clearly defined or fully understood.

As thermic, luminous or chemical factors may preponderate in the action of radiant energy, its relation to animal hygiene may be presented in accordance with this preponderance.

Caloric Radiation.—As has already been pointed out in another chapter, the metabolism of all higher animals is dependent on the maintenance of temperature within a narrowly defined range. This is largely achieved within the animal body as a result of metabolic combustion. Animal well-being is also subject to the thermic influence of the ambient atmosphere, and in the determination of what are called climatic phenomena, heat is a principal factor.

Directly or indirectly, practically all heat is derived from solar radiation: from the dark, infra-red rays as well as from the caloric rays of the visible spectrum. The heating of the earth and its atmosphere comes about by direct solar radiation, whereas body or metabolic heat is nothing more than the setting free of the latent energy stored by the sun's rays. In the heat production from fuel, the same process is involved.

The amount of heat which solar radiation delivers to the surface of the earth has been calculated to be so great that it would be sufficient to cause the melting each year of a sheet of ice 100 feet in thickness covering the entire surface of the globe. Of this stupendous amount of heat, however, a considerable portion is retained by the atmosphere, principally absorbed by atmospheric moisture.

With a perpendicular incidence of the caloric rays at sea level and with a clear sky, only about 64 per cent of the rays reach the surface and about 36 per cent become absorbed in transit. The absorbed rays are, however, not entirely lost, for in the shape of "diffuse" radiation they are made available to plants and animals which are favored by the influence of this absorption, which tempers radiation in both directions and aids in the maintenance of equable climatic conditions.

Atmospheric absorption of radiant energy is selective in its action, and the rays of different wave lengths are retained in different degrees. Ambient heat has a potent influence on the heat regulation

of the body, which, during intensive solar radiation, may be so interfered with as to give rise to the condition of sunstroke or insolation; in the opposite extreme its absence or deficiency may lead to chilling or actual freezing.

The theory has been advanced that insolation is principally due to the action of the chemical rays, but the evidence seems conclusive that it is entirely associated with the simple over-heating of the body through interference with heat elimination.

For the prevention of insolation, the same measures must be taken as are directed against the occurrence of heat stroke, resulting from excessive humidity in combination with a high temperature and not uncommonly induced by muscular activity. Rest in a shady and airy place, frequent opportunity to drink, suitable diet and even the application of water to the body surface are all measures which will tend to lessen the danger of sunstroke to animals exposed to intense caloric radiation. Animals so susceptible to over-heating as sheep and fat swine should not be over-crowded in sunny places or rapidly driven in close formation when exposed to the hot sun of a summer day.

The use of straw hats or wet sponges adjusted to horses' heads offers no protection against heat stroke as only a small part of the body surface can thus be shaded; indeed, it is by no means impossible that such devices do more harm than good by their interference with air movements which tend to carry away excessive body heat.

The practice of stabling and sheltering animals as well as the use of blankets are designed to prevent excessive heat losses, when solar heat becomes deficient. Care of the hair coat, by grooming, likewise assists in the prevention of chilling by rendering it more efficient as an insulating medium.

The caloric rays intensify the bactericidal action of the chemical rays and when of sufficient intensity and duration of application become themselves active in the destruction or inhibition of germ life.

Luminous Radiation.—Of the greatest physiologic importance because of its relation to vision, light has, however, not the degree of importance in the hygiene of domestic animals that it has in man. The long years of the most exacting duty which man imposes on his optic apparatus, the greater chance of the factor associated with senile changes in the human eye as well as the further factors of indoor work and artificial lighting have emphasized the importance of light in the practice of ocular hygiene.

In the domestic animals, in which the preservation of correct vision is of relatively minor importance, which, as a rule, are better

equipped to meet the extremes of luminous irritation of their optic apparatus, and in which artificial light sources are usually not a factor at all, luminous radiation has but little more than a purely physiologic importance.

Veterinary ophthalmologists rarely mention the influence of light as a source of visual disturbances. It has been suggested, however, that rays of a certain wave length may be implicated in the causation of parenchymatous keratitis and that senile cataract may be due to the protein-coagulating action of light. There can be no doubt that forcing animals to face a glaring light (by the faulty placing of stable windows, for example) is quite contrary to the principles of hygiene. Under ordinary, everyday conditions, animals will avoid such exposures on their own account.

Although the influence of light is commonly ignored by veterinary writers as an etiologic factor in ocular diseases, it is a well-established fact that it may materially aggravate many such disease processes already active, and in their management and treatment one of the first and most important requisites usually is the tempering of the light admitted to the eyes or the exclusion of it altogether.

The influence of light on animal well-being and health is generally recognized, and though but ill understood it has been regarded as of beneficial potency since ancient times. Its psychic effect is marked; under the influence of luminous radiation the erythrocytes are increased in number, and the general metabolism is more active in the light than in the dark. When animals are kept in the dark, fattening is favored by the inhibition of some of the more destructive phases of the metabolism.

Curves representing the amount of invalidity shown during the different months of the year and the amount of daylight present show a marked latency in the invalidity curve, the maximum of which is reached some six weeks after the shortest day whereas the minimum is even later after the longest day. Light appears to extend an influence for good upon health, so that in the summer months a resistance to disease is built up which is only slowly dissipated during winter.

Light in inhabited spaces promotes cleanliness on the principle that filth unseen is commonly filth left undisturbed. It thus becomes a material aid in the practice of stable hygiene as well as an important factor in efficient management.

Artificial light, lengthening the feeding day, is now being used by poultrymen, so that more eggs can be produced during the winter.

In this manner egg production may be so increased that 100 fowls will lay from 50 to 60 or even 70 eggs per day.

Aside from the influence of light due to mere luminosity, its chemical energy within the range of the visible spectrum must also be given consideration on account of its hygienic aspects. Although this is most pronounced in the case of the invisible, short-wave, ultra-violet rays, the violet rays of the spectrum are endowed with potent chemical action.

The violet rays and the blue ones to less degree are not only disturbing and damaging to living protoplasm, but also to various ferments and bacterial products. Though the influence of dark short wave rays cannot be denied, solar radiation may cause in animals exposed to it a dermatitis of the more tender, sparsely haired and unpigmented portion of the integument. This is not uncommonly seen in young pigs, lambs, and in horses about the lips and nostrils. There is evidence to show that the sun may have an influence on the blood which it brings to the surface, and the erythema of an increased metabolism in the skin set in motion by solar radiation may have a bearing on the maintenance of immunity.

It is probable that the light effects on the skin are almost exclusively due to the ultra-violet rays, yet it is of interest to note that certain substances of a fluorescent nature may sensitize the living tissue in such a manner that the visible sunlight can act energetically enough to become equivalent to radiation by the purely chemically acting short-wave rays. Under the influence of such photodynamic substances, luminous radiant energy is changed to chemical energy, and the lethal power of light may thus be increased very materially.

Solutions of eosine are particularly noted for their photo-dynamic action. Mice injected subcutaneously with such a solution and exposed to intense lumination develop a severe dermatitis resulting in gangrene of the ears and the skin and in the loss of hair, whereas control animals kept in the dark suffered no inconvenience. Barley denatured by means of eosine is generally quite harmless when fed to pigs as long as they are kept out of the sunlight, but when exposed to such radiation fatal disease may develop.

A similar condition is apt to come about in cattle and sheep fed with buckwheat, which normally contains a fluorescent substance. The animals suffer no inconvenience if kept in the dark, but when they are exposed to the sunlight a dermatitis of the non-pigmented skin is apt to develop. This condition is known as fagopyrism; it may be accompanied by the loss of hair and by gangrenous lesions of certain parts.

Photodynamic action has been attributed to other plants, such as clover, alfalfa, potato vines and many more. It is not impossible that the dermatitis observed when animals dipped in crude petroleum are exposed to the bright sunlight can be explained in the same manner.

Light is endowed with bactericidal powers, especially associated with the rays of the shorter wave lengths. The red, orange and yellow rays are practically inert with regard to bacterial life; ultra-violet rays are the most active in this respect.

The abiotic action is powerful for the wave lengths of 200 millimicrons, rapidly diminishing for radiations between 210 and 230 millimicrons. From 250 millimicrons to 310 millimicrons the effect is relatively feeble and decreases slowly, apparently ceasing altogether at 350 millimicrons. It was found that the action at 215 millimicrons was about 25 times greater than at 250 millimicrons and several hundred times greater than at 300 millimicrons.

The action of light on micro-organisms is materially modified by the influence of factors such as moisture and dryness, oxygen and temperature. The intensity of the radiation also plays an important part, and its action is limited to the most superficial layers of the medium in which the organisms are contained.

The more active bactericidal rays are arrested by ordinary window glass and are detained by water, especially if the latter is turbid. Light promotes oxidation and drying and thus enhances cleanliness. Sunlight alone cannot be depended on as a disinfectant of indoor spaces, but in combination with some of the factors mentioned it helps to destroy the pathogenic elements suspended in the out-door air. It contributes to the purification of water by its action on the most superficial layers. Slight as its demonstrable action may be, there is reason to believe that the luminous rays enhance the salubrity of the environment in which animals live.

Chemical Radiation.—Clinical observation of the past, supported by a considerable volume of experimental evidence accumulated during more recent times, has definitely shown that the ultraviolet radiation endowed with purely chemical energy exercises a potent influence on animal metabolism. To such action must be attributed the well-known fact that people exposed to the more intense heat rays (glass blowers, stokers, foundry men, bakers, etc.) fail to develop either a dermatitis or even the pigmentation of the skin like individuals exposed to solar radiation, whereas mountain climbers exposed to the sun in the icy environment of snowfields and glaciers become markedly sunburnt and tanned (glacier burn). The results obtained by natural and artificial

heliotherapy also indicate that the dark, chemical rays of the sun and other sources have a manifest effect on the course of a number of pathologic conditions.

Solar radiation contains ultra-violet rays down to wave lengths of about 290 millimicrons. The rays of wave lengths of between 290 and 310 millimicrons are not transmitted through glass, although most types of glass are quite transparent to the near ultra-violet to wave lengths of about 350 millimicrons. From that point on, the transparency rapidly falls to practically zero at 300 millimicrons.

Quartz crystals were found to be transparent to wave lengths to 185 millimicrons, exceptional specimens transmitting rays even as short as 145 millicrons in wave length. The transparency of fluorite extends even further into the ultra-violet region.

The transparency of thin sheets of celluloid and photographic films exceeds that of glass. Solar ultra-violet radiation is absorbed by the atmospheric water vapor to a considerable extent, and as a general rule most substances are increasingly opaque to ultra-violet radiation with the shortening of the wave length.

The short-wave limit of transparency of the cornea coincides with that of the visible spectrum. In the experiments designed to reveal the influence of ultra-violet radiation, use is made of artificial sources, among which the quartz mercury vapor lamp is perhaps most commonly employed. Such lamps yield a visible light and also emit ultra-violet rays down to wave lengths somewhat below 200 millimicrons. Both for clinical and experimental purposes the use of such sources of ultra-violet radiation offer certain advantages. Solar radiation is always subject to irregularities associated with meteorological conditions, and also the radiation from the lamps are perhaps 30 or 40 times as potent as those provided by the sun. Much of the knowledge of the action of ultra-violet rays on the body was secured through the use of some artificial source of radiation.

The effect of ultra-violet rays on the animal body appears to be most potent in connection with the metabolism of calcium and phosphorus. It is especially the discovery of their influence on rickets that has stimulated the researches upon which our present knowledge of the subject is founded.

The part played in the prevention and cure of rickets by ultra-violet radiation is quite striking. The rays not only have a curative action on rickets, which results from a deficiency of either calcium or phosphorus, but in cases in which both factors are in default, it inhibits the calcium elimination and loss and thus ameliorates the

consequences of the deficiency to the skeleton and to the metabolic functions in which calcium plays an essential part.

Only a narrow band in the ultra-violet region of the solar spectrum appears to be of value in the cure or prevention of rickets. Rays of a wave length of 324 millimicrons have little or no value in this respect, but those of 302 millimicrons are endowed with a decidedly beneficial action.

In experiments with chicks restricted to a diet which caused the development of rickets in from 4 to 6 weeks in control animals kept behind glass, it was found that an exposure to direct sunshine for about 45 minutes on bright days was quite sufficient to prevent the disease.

Other morbid processes in which a faulty calcium metabolism appears to play a part may likewise be favorably influenced by ultra-violet radiation. Under its influence, cases of infantile tetany were given progressive and permanent relief, and this was paralleled by the return of the serum calcium concentration to an eventually normal level.

It is quite apparent, thus, that this form of radiant energy supplies something to the body which decidedly favors the retention and assimilation of calcium compounds. Not only is this the case in young animals, but also in adults, in which the storage of calcium and phosphorus and the maintenance of the balance of these elements is directly or perhaps indirectly subject to the action of ultra-violet radiation.

Of absorbing interest is the discovery that not only exposure to direct ultra-violet radiation affects animal metabolism, but that the consumption of irradiated foods and other substances may also lead to the same results. It was found, namely, that a ration which induced rickets in young rats can be rendered definitely anti-rachitic by the simple expedient of exposing it to ultra-violet radiation, bringing results equivalent to those secured by the direct irradiation of the animals themselves.

Such foods as dried milk, flour and spinach were rendered anti-rachitic by radiation from the quartz mercury vapor lamp, and in the case of spinach this potency was retained after it had been boiled for half an hour.

Etiolated wheat plants were found to have no anti-rachitic qualities, but wheat grown in the light and irradiated with the quartz mercury vapor lamp prevented rickets when fed to experimental animals. Green lettuce leaves were of no value in preventing rickets, but when irradiated they conferred protection to the animals fed with them.

Two groups of young rats on a standard, low-phosphorus, rickets-producing diet were given a definite supplement of skin. One group received ordinary skin and the other group was fed skin that had been suitably irradiated. It was found that all the animals fed on non-irradiated skin developed rickets, whereas those which received irradiated skin were adequately protected against the disease.

In a child receiving ordinary milk only a slight increase in the amount of calcification at the distal extremities of radius and ulna could be observed, whereas two children fed on milk that had been exposed to the ultra-violet radiation presented evidence of a dense calcification in the same structures.

Even the organs of animals which were exposed to short-wave rays appear to become endowed with growth-promoting properties. Liver, lung and muscle taken from irradiated rats apparently favored normal development, whereas the identical organs obtained from non-irradiated rats proved to be inactive.

Cottonseed oil when irradiated had acquired anti-rachitic qualities, and the same result was obtained with irradiated linseed oil, namely: the development of rickets in the animals fed with non-irradiated oil and the prevention of rickets when irradiated oil was given.

It seems quite probable that solar radiation of foods is not as potent in bringing about anti-rachitic qualities as that secured by means of the more powerful artificial sources under experimental conditions. The results obtained are, nevertheless, extremely significant in that they show the marked potency of radiant energy in its relation to biologic processes.

Indirect action of radiant energy may be the factor responsible for anti-rachitic growth-promoting qualities of cod-liver oil. The similarity between the action of the oil and that of radiance is so close that there is reason to believe that there is a connection between them.

The modus operandi of radiant energy as a factor in the promotion and regulation of the calcium-phosphorus metabolism and the functions which are dependent on the latter is as yet a matter of conjecture.

The fact that the action of radiant energy can be acquired by many intermediary substances appears to eliminate a direct catalytic action of the rays. It is possible that the rays of short wave length can so change certain compounds as to render them effective as catalists. It is suspected that sterols, such as the cholesterol of animals and the phytosterols of plants, may play a part in this function, but the relation of these substances to the anti-rachitic properties of ultra-

violet rays has as yet not been definitely removed from the realm of hypothesis.

The initial action of ultra-violet rays is confined to the most superficial layer of the skin inasmuch as the rays can penetrate only to a slight depth, the presence of the circulating blood apparently being a principal factor in bringing about this limitation.

Evidence has been submitted that the activated substance must be absorbed into the blood and distributed throughout the body, that in a manner, yet unknown, it profoundly affects the normal growth and development of animals and that it adds to the defensive power of the body. This defensive power cannot be attributed to such bactericidal effects as the rays may bring about, but to such products of tissue damage as may arise in the irradiated skin as well as in skin subjected to the action of blisters, heat and other agents of this type. In some way, such influences tend to set in motion the protective or immunizing mechanism.

This is supported by evidence which shows that the blood serum as well as the leucocytes contributed to the increased bactericidal action of the blood of rabbits exposed to irradiations sufficient to produce a dermatitis. Similar results were obtained in pigs and to a less degree in man.

It appears now to be quite certain that exposure to ultra-violet radiation is a requirement for the normal development of young animals and for the continued well-being of adults as well.

Short-wave rays either from the sun or from artificial sources not only will prevent rickets (leg weakness) in growing chicks, but they also have a marked effect on egg production, as shown by the number of eggs produced, their chemical composition and their hatchability. They are likewise a favorable factor in the production of pork under conditions of confinement in northern latitudes, and they have a direct bearing on the maintenance of the calcium-phosphorus balance in dairy cows. In this connection it is probable that direct exposure to solar radiation is of more practical importance than the more indirect influence of the tissues of green plants which were exposed to the same influence.

In the light of the available knowledge of the action of ultra-violet radiant energy, its consideration in the hygiene of animals is fully warranted. In animals daily exposed to out-door conditions, the problem is of negligible importance, but in the case of those continuously confined in enclosed spaces, its solution constitutes a task deserving the attention of the hygienist.

However important the adequate lighting of stables may be from a general sanitary viewpoint, the fact remains that window glass constitutes an effective barrier to biochemically active ultra-violet rays. Most domestic animals are frequently enough exposed to the unfiltered radiation available in the out-of-doors, but with the common tendency of having young animals born or hatched at a time well in advance of the warmer season, they are apt to remain deprived of direct solar irradiation for long periods and that at a stage of life when a normal calcium-phosphorus assimilation is most essential.

This handicap, no doubt, is in a measure reduced in the case of the young mammals which are nourished with the milk of dams, habitually or even occasionally exposed to out-door radiation. The same compensatory influence may be active in chicks as long as they derive substance from the yolk. The occurrence of rickets, leg-weakness, subnormal growth and other conditions which may be attributed to "light starvation" indicates that either a deficiency in the needed minerals, in exposure to ultra-violet radiation or possibly a combination of these factors is to be reckoned with.

Assuming a diet in no way deficient in the nutritive and mineral constituents required for maintenance and growth, the activating and economizing influences of ultra-violet radiation may be supplied by periodic exposure to solar radiation. Even in winter there are times when unfiltered sunlight can be admitted to a stable without risk of unduly chilling the animals. Or the animals may from day to day be exposed in a sheltered place outside. Experimental evidence shows that such an exposure need not be prolonged beyond 45 minutes per day. Direct sunshine does not appear to be imperative in this matter, as it has been noted that even on sunny days more ultra-violet rays come from the sky as a whole than directly from the sun, and this is particularly the case when the sun is low or obscured by clouds.

Whether or not the use of irradiated foods will have a place in the rearing of young animals cannot be foretold at this time, but when natural sources of radiant energy are for some reason not available, the daily addition of an adequate quantity of cod-liver oil may at least in a measure compensate for the insufficiency. In certain select cases the irradation of the animals by means of the quartz mercury vapor lamp may be resorted to.

Window glass, no doubt, is a principal obstacle to the admission of the desirable radiation in stables as well as in houses. As one author aptly remarks: "Window glass has unquestionably accelerated the speed of civilization, but man has paid the price." The substi-

tution of a more permeable substance for glass may come to be recognized as an important problem in hygiene research.

Owing to the greater permeability of celluloid to ultra-violet rays as compared with glass it is possible that its use may come to have a place in the window frames of structures used to shelter young animals during the seasons when their exposure to out-door conditions is not desirable. Offered as "flexible glass" or under other trade names, such substitutes for glass are now available in commerce. One specimen examined by the author had a framework of coarse-mesh wire cloth which was treated in such a manner that the open spaces were filled with a transparent, tough, flexible celluloid-like material. Evidence to prove its value as a medium capable of transmitting ultra-violet rays in a manner sufficient for beneficial biochemic action acquired by a more or less general use, is, however, not yet available at this time.

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CHAPTER VIII

WEATHER AND CLIMATE

Weather.—Atmospheric phenomena have always occupied a prominent place among the influences of environment which man regards as most potent for good or for evil so far as his own well-being and that of his livestock were concerned. Weather and its effects, the most appreciable of all manifestations of nature, have ever aroused his interests, and the lore which developed around this subject during the ages bears abundant testimony of the belief that the state of health or of disease was in a large measure weather born. The term "weather" pertains to the conditions of the atmosphere at a definite time. This is determined by the effects of temperature, humidity, air movement, pressure, radiant energy and electrical phenomena.

Weather Influences.—In the appropriate chapters, consideration has been given to some of the physical qualities of the ambient atmosphere and the manner in which they may influence the animal body and its functions. It was pointed out that although the range between the limits of what constitutes an optimum living condition is a rather restricted one, the animal body possesses such a power of accommodation and adaptation that it is quite capable of adjusting itself readily to ordinary atmospheric deviations from the mean, and that it can even endure for a considerable time the more extreme departures from what is most suitable.

These changes are particularly to be named among the influences which weather may exercise on animal well-being, and to them must be added the rapidity by which they may come about. The adjustment to whatever variations in the physical state of the atmosphere may take place is not always as prompt as the suddenness of a change may demand, and during the interim the animal concerned may be subjected to results which are adverse to the maintenance of a normal state of health. So far as meteorologic influences alone may affect animal health, mention must here especially be made of such factors as temperature, precipitation, wind and electrical manifestations.

Extremely high temperatures may so disrupt the heat-regulatory

functions of the body as to produce insolation or heat exhaustion; excessively low temperatures may cause the freezing of such remote portions of the periphery as the tail, the ears, the teats, the comb and wattles, and if, as a result, the blood circulation becomes suspended beyond a certain length of time, gangrene of the parts may be the ultimate effect.

Even relatively moderate reductions in the temperature coming about in a short space of time may assert themselves as harmful factors. A large volume of opinions based on empirically acquired knowledge points to such chilling of animals as an important etiologic factor in certain diseases. Without doubt, much of this opinion is quite erroneous and must be abandoned in the light of more exact information. To eliminate chilling or the exposure to cold, damp weather as more or less important factors of etiologic importance would, however, be an error. Whether alone or as merely predisposing factors to certain infections, their influence, direct or indirect, cannot be readily dismissed in certain catarrhal affections of the upper air passages, in the conditions which are still designated as rheumatism, in those contributory to the causation of azoturia, and in connection with certain forms of founder. The latter disease has frequently been observed in horses which were subjected to applications of cold baths in the face of menacing aspects of severe over-heating, and in a number of such cases this rather heroic treatment was apparently responsible for the development of pleuritis.

In spite of many plausible theories, the pathogenesis of chilling is as yet a matter of conjecture, but there is no warrant to deny the potency of this influence. Exposure to cold is often badly borne by the new-born, and young pigs and chicks are quite susceptible to the effects of low temperature and not infrequently succumb as a result.

Prolonged exposure to rain is capable of producing an excessive loss of body heat, if the atmospheric temperature is low. Continued rainy weather during a comparatively mild season may seriously affect the skin and its appendages. Sheep exposed to such conditions may suffer from decay of the fleece, and horses with heavily feathered legs may be subject to a stubborn dermatitis of the region of the cannon and pastern when continued exposure to moisture causes a maceration of the skin covering those parts.

Precipitation in the form of hail has commonly been disastrous to young chickens if they were caught by it when removed from shelter.

Strong winds, accompanied by very low temperatures, may be fatal to livestock and especially so whenever an adequate supply of food is

lacking. The great losses of cattle occasionally experienced on our northwestern plains are usually due to the factors just mentioned.

The electrical phenomena of the atmosphere have apparently no appreciable effect on the animal body, but in the form of lightning they may occasionally cause the death or injury of animals directly in the path of the discharge or when they are in close proximity of such conductors as wire fences or of projecting objects as trees or poles when the latter are struck.

Hygienic Considerations.—On the whole, the domesticated animals adjust themselves so readily to changed meteorologic conditions that special hygienic measures need not be taken. Whatever is undertaken in that direction consists largely in the protection against weather influences of an extreme nature and in so managing livestock that its capacity for adjustment and adaptation is not over-taxed.

Stables and other forms of shelter have from early times been provided as a protection against atmospheric inclemencies, although from a hygienic point of view they have not always proved to be free of disadvantages.

The danger to animal health which may be associated with high temperatures may be averted by an adequate provision of shade, by free access to drinking water, by a reduction in muscular exertion and by allowing animals at work frequent intervals of rest.

Suitable shelter, the use of blankets and increased muscular activity have a value in the protection against cold, but in most exposures of this sort and especially during periods of extremely low temperature, accompanied or not by strong winds, an abundant supply of suitable food remains the most efficient form of protection against these harmful influences.

The use of artificial heat as a protection of livestock is not a common practice for the larger, well-nourished animals. It may, however, find application in the case of newly born pigs and incubator chicks. The former, when properly housed and provided with an abundance of dry bedding, will require additional protective measures on but few occasions. This may be suitably accomplished by placing a jug filled with hot water in a wooden tub large enough to afford room for the pigs, so that they cannot smother by excessive crowding (Fig. 37). This arrangement may be supplemented by a cover consisting of a dry, woolen blanket loosely applied.

For incubator chicks or poults, artificial heat is usually an imperative necessity. Such brooding equipment usually consists of a suitable constructed space heated by a brooder stove utilizing coal or oil

as fuel, or by an electric heating device. The brooder stove is equipped with a so-called hover, consisting of a conical metal cover provided with a curtain for heat retention (Fig. 38). The movable colony brooder house is the most desirable for this purpose as it affords the essential advantage of permitting the selection of clean ground to be occupied by the young birds.

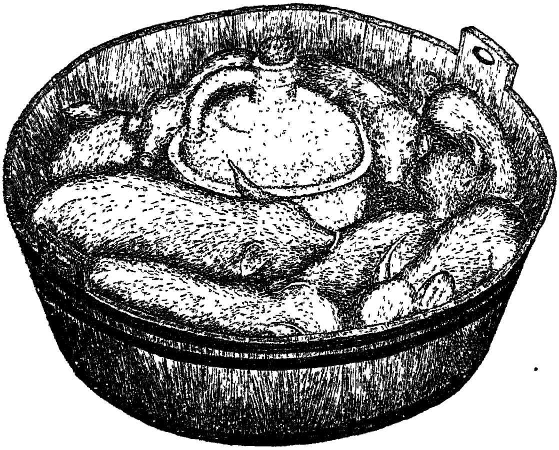

Fig. 37.—Emergency protection of new-born pigs against chilling.

The brooder house should have a floor area of about 1 square foot for every 3 chicks. More than 500 chicks should not be brooded in one house, and the best results are commonly obtained if only 250 chicks are brooded at a time. The house should

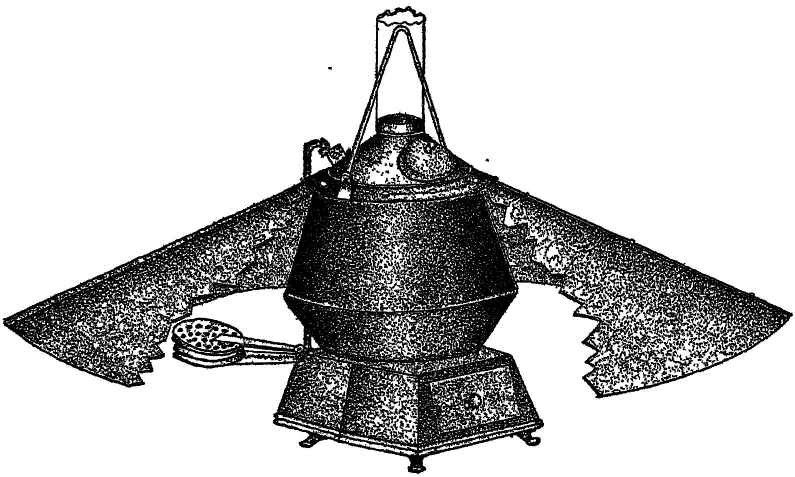

Fig. 38.—A common type of brooder stove.

be heated for two or three days before the chicks are admitted and this period should be utilized for the regulation of the heating ap-

paratus. Before the house is occupied, its floor is covered by a thin layer of sand on top of which a 1-inch layer of alfalfa meal or clover leaf chaff is placed.

The temperature to be maintained under the hover varies somewhat for different climatic conditions, but a heat of 100° F. shown by a thermometer placed on the floor near the outer edge of the hover will usually meet the requirements. As the chicks become more vigorous, this temperature may be gradually reduced. If the chicks at night collect around the edge of the hover without crowding, there is reason to believe that a suitable temperature is being maintained.

A stove with a 52-inch hover will accommodate 500 chicks, and the

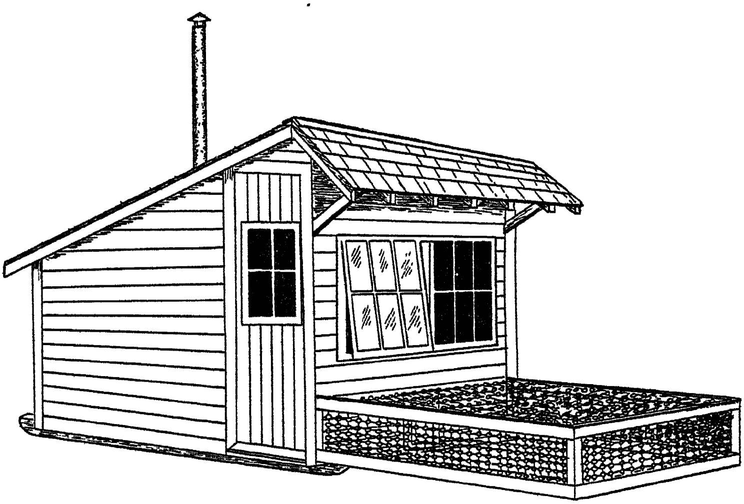

Fig. 39.—Brooder house with solarium.

space thus provided is recommended whenever more than 250 chicks are to be brooded in one lot. For the first two nights it is advisable to place a narrow strip of wire netting around the outside of the hover in order to prevent the chicks from straying too far from the heat.

Ordinarily, animals out in the open air do not require special protection against rain, but horses continually at work during prolonged rainy weather may be benefited by some water-proof material covering the upper part of the body, and a similar contrivance may be advisable in the case of heavily fleeced sheep living under like circumstances. Open sheds available to animals at pasture offer a desirable protec-

tion against prolonged cold rains as well as against strong winds, and they certainly have a decided hygienic value in this connection.

The proper grounding of metal fences discussed in another chapter is also to be regarded as one of the hygienic measures by which adverse atmospheric conditions are to be met.

Climate.—Whereas the term "weather" pertains to an atmospheric condition or phenomenon at a given time, the word "climate" designates the averages and extremes of meteorologic manifestations which are peculiar to a given locality. In a sense, the climate of a region is the average of its weather.

Latitude is the principal factor which establishes a climate. It determines the position of the sun toward a given region of the earth and governs the duration as well as the intensity of solar radiation for the section concerned. The effect of latitude may, however, be materially altered by altitude, the temperature falling about 1° F. for every 300 feet of additional height.

Among secondary, although often very potent, influences on climate are the relative distribution of land and water, the proximity of a region to ocean currents, the shelter furnished by mountain ranges, the rainfall, the prevailing winds as well as the soil and the vegetation it sustains.

Although sharp lines of demarcation between the various types of climate cannot be drawn, it is, nevertheless, possible to distinguish climatic zones which present characteristic features.

The climate of the tropical and sub-tropical zone is marked by a regular periodic appearance of its meteorologic phenomena and the absence of the irregular weather changes peculiar to the climates in regions having a greater latitude. Seasonal meteorologic differences are largely obliterated. During the period of the trade winds there usually is dry weather, and when they cease a rainy period begins. During this time the cloudiness and precipitation bring about a certain degree of cooling, but this is not comparable with the winters of the temperate climate zones.

The antithesis of the tropical climate is that peculiar to the arctic zones. There, seasonal meteorologic differences are most marked. Solar radiation is absent during the entire winter, which is extremely cold. Even the summers are cool within these zones, largely on account of the great masses of snow and ice which absorb a considerable portion of the available heat during the process of melting. Fogs and precipitation are common in summer, which is further marked by almost continual daylight.

Between the zones mentioned lies the temperate zone, marked by more moderate meteorologic qualities and by a rotation of seasons which, by their weather changes, have a profound influence upon all biologic forms. More than in the arctic and tropical climatic zones is the climate of the temperate zone influenced by modifying factors. In sections in close proximity to the oceans, the heat of summer as well as the cold of winter are tempered by the presence of the great expanse of water. We then speak of a marine climate in contrast to the continental climate, where the moderating influence of the sea is no longer a factor and where, in consequence, the winters may be fiercely cold and the summers intensely hot. A separate position is given to mountain climate peculiar to the regions of high altitude. There, solar radiation is most intense, but the temperature is lower. Absolute humidity is low and relative humidity high. Atmospheric pressure is reduced, and the ambient air is free of dust.

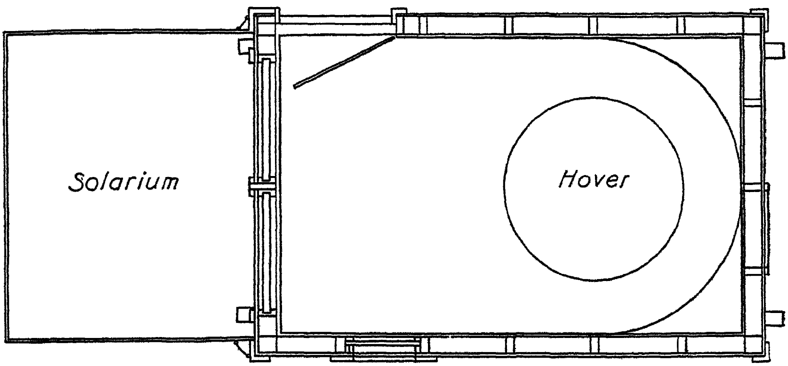

FIG. 40.—Ground plan of brooder house with hover and solarium.

Accessory Influences.—The purely meteorologic phases of climate were for a long time regarded as the principal if not the only ones which had at all to do with the influence on animals. No doubt, these weather characteristics are important factors, but so far as they affect animal life in a direct manner, they are secondary to the more indirect way by which a climate may be wholesome or harmful to livestock.

Climate in a large measure determines such fundamental living conditions as food, competitive, predaceous or otherwise harmful animals and the pathogenic factors which may be maintained in a given region. From a hygienic standpoint, the term climate must include not only the meteorological peculiarities of a region, but also its soil and topography, its flora as well as its fauna. A knowledge of these

factors must be supplemented by more or less precise information of the more prevalent or enzootic diseases and their ways of transmission whenever climate is to be hygienically considered.

It would probably be erroneous, or at least inadequate, to ascribe the seasonal fluctuations in the prevalence of certain diseases to direct meteorological influences only. No doubt, such factors as temperature are ruling forces in all biologic processes, but most frequently they exercise their influence in a very indirect manner.

The purely meteorological qualities of climate are probably most potent in the temperate zones, where animals are exposed not only to frequent and sudden changes of weather, but where each year they are forced to adjust themselves to the change from summer to winter, and vice versa, and to the intermediate seasons of autumn and spring with their capricious weather conditions. There is much evidence which suggests that the burden thrown on the animals' power of adaptation may be upsetting to their physiologic equilibrium, which is apt to express itself as a greater liability to intercurrent pathogenic factors.

It is probably quite true that aside from the effects of sudden changes the meteorologic features of climate have had a greater influence on the racial peculiarities of domestic animals than on merely individual well-being. Much of the organic equipment which renders a given breed peculiarly fit to live or to survive in a certain environment has been developed under stress of climatic influences. Thus may be explained the thickness of hide and shagginess of hair coat of cattle and other forms of livestock inhabiting regions marked by cold or otherwise inclement climates.

Hygienically viewed, certain accessory or indirect influences are often more important than the weather aspect of climate, and when, for instance, the climate is spoken of as unwholesome, it may upon investigation, turn out that this unwholesomeness is more determined by entomologic or even sanitary factors than by purely meteorologic influences.

Physiologic Considerations.—Both by direct and indirect action, climate largely determines the animal species which, in the wild state, can maintain themselves in a given region, although other factors may also exercise an influence. For instance, over-population and the resulting competition for food may have a profound influence on the surviving possibilities of a given species.

As a rule, a species is adequately adapted to the climate of its home range, but there is ground for the belief that, in a large number of

the individuals comprising it, there remains a latent power of adjustment or accommodation to a changed environment which permits the animals to survive under different climatic or environmental conditions.

The position of the domesticated species is, however, somewhat different from that of animals living in the wild state. Their native plasticity which in the first place rendered them fit for domestication has not become diminished in this long and tedious process, and a ready accommodation to widely different climatic conditions may thus have come about. It is further significant that domestication and the type of animals it brought forth reached their highest perfection within the temperate zones, where often marked extremes of climatic phenomena forced the species concerned to maintain their inherent capacity for adaptation to a high degree.

The need of meeting the annual changes in climate through countless generations cannot fail to have had its effect on the remarkable power of adaptation displayed by the domesticated species. To these features must be added the part played by man, by which at least most of the adverse climatic conditions may be eliminated or neutralized so far as they are understood. That, even under this influence, all climatic disadvantages cannot always be overcome does not in the least change the fact that the domesticated species are less dependent on a climatic optimum than animals living in the wild state.

The domesticated species, however, have retained certain preferences in regard to climate and may not always thrive equally well in all environments. The horse can withstand intense cold, and wild herds are found to prosper on the plains of Siberia where the most bitter cold often prevails. Originally, the equine species must have inhabited regions commonly covered by snow, as shown by the instinctive scraping away of it in the search for food which the ages of domestication have not yet obliterated. This animal may also prosper under intense heat, for it has reached its highest perfection in such countries as Arabia and northern Africa. Mountain climates are less suitable for the horse, and in some tropical countries it tends to become reduced in size. On the whole, this species shows a marked quality of adaptation to widely varied climatic conditions.

The bovine species, with its thicker and more resistant skin, is more adapted to the colder regions than to warmer climates, and the northern breeds commonly show a reduced productivity in the tropics.

There is some evidence which shows that sheep, on the whole, are

more adversely influenced by a change of climate. Great heat seems to act directly on the fleece; European sheep imported into the tropics, after the third generation lose their wool from the whole body except from the region of the loins, and the animals assume the appearance of the goat. Such changes are, however, not a constant feature and may be due to influences the nature of which has not yet been determined. At least, wool-bearing sheep may be found on the hot plains of India, and the preservation of the Merino breed in its utmost purity at the Cape of Good Hope, in the marshes of Holland and under the rigorous climate of Sweden indicates that a fine-wooled sheep may be grown wherever good practices of animal husbandry and intelligent supervision of breeding are persisted in.

Sheep tolerate cold better than any other domestic species, but they suffer far more from heat, and in the warmer climatic zones their fecundity is apt to become reduced.

Swine thrive best in a temperate climate and especially when there is no excess of humidity. They tolerate great heat quite badly and especially so when they are caused to exert themselves unduly or when they are closely massed together in confinement.

Hygienic Importance.—To animals adapted to whatever the environment of their home region has to offer, the hygienic importance of climate is largely associated with such influences as the atmospheric phenomena designated as weather may have on them. To such animals, climate *per se* presents but few, if any, problems of a hygienic nature, provided their adaptation has been a complete one and provided they remain where they are.

Although this is true, attention must be called to the seasonal fluctuations in the prevalence of certain diseases, even if it is by no means certain that climate alone is the principal and direct factor in the modification of morbidity. These fluctuations are most pronounced in the temperate zones in the major area of which a semiannual change of climate occurs with a similar change in living conditions for which climate may be more indirectly responsible. The interim extending from summer to winter, for instance, is commonly marked by sudden changes of weather, and at the same time the livestock may be as suddenly changed from a life in the open air to confinement in a stable and from a régime of green food to a dry diet. The same changes, although in an opposite direction, have to be met with in the spring, and although atmospheric qualities may help to bring about a more or less seasonal prevalence of certain diseases, there can be no doubt that the burden placed upon the animal's

capacity for adjustment to varying conditions of living may profoundly change their susceptibility.

In other cases in which morbidity is modified by season, the causes may lie entirely outside the animal body. Certain diseases transmitted by biologic vectors naturally will be more prevalent when the prevailing temperature is favorable to the latter, and the same factor may operate similarly in many of the parasitic diseases.

The effect of season on the food and its quality may also help to account for the seasonal appearance of certain disorders. Bloat in ruminants, for instance, has a most decided seasonal morbidity because it is intimately associated with the state of certain forage plants and the meteorologic influences to which they may be exposed. Cholera infantum induced by milk which became putrid under the influence of higher temperature is not due to the effect of climate on the children, but to a more indirect factor: the temperature suitable for the growth of bacteria.

It is probable that, in certain of the communicable diseases, the opportunity for dissemination is by no means the same for all seasons. During the winter season, when livestock is concentrated in stables and yards, the opportunity for the spread of disease in a given herd is greater than it would be in summer when the animals are scattered over a range or pasture. Yet, in such a disorder as foot and mouth disease this very scattering may become responsible for a much wider dissemination than would take place when the ruminant population were gathered in denser units.

Although the seasonal behavior of certain diseases must, of course, be recognized, it is not probable that the direct action of climate on the animals can, in all cases, be held accountable for the phenomenon. Its action is probably intricately indirect and its influence so subtle that we must acquire much additional knowledge of the subject before it will be possible correctly to evaluate the climatic factors which may have to do with its occurrence.

Acclimatization.—The term acclimatization became current during a period when all morbid manifestations on the part of man and animals recently removed from the environment to which they were adapted were ascribed to the differences in climate presented by the new place of abode or range. No doubt, the merely meteorologic qualities of the new home cannot always be dismissed as entirely innocuous, but on the whole, whatever hygienic importance may be attached to them is vastly overshadowed by other factors having

either a very remote and indirect connection with climate or none at all.

The acquisition of a more exact knowledge of etiology has given a new meaning to what was once considered to be an imperative process of acclimatization, and in accordance with the newer information we no longer attribute the fatal cattle disease to which northern bovines succumbed in the southern part of the continent to the influence of climate, but look upon it as a penalty for the invasion of the distribution area of the cattle tick by highly susceptible mammals. Nor is the climate held any longer responsible for the so-called shipping fever or infectious pneumonia of horses transported to eastern or southern markets, after it became evident that it was due to a strictly specific infection acquired by retention in more or less permanently infected stock yards and horse markets.

However, the term acclimatization, though to a large extent a confusing misnomer, is still retained to designate the combination of measures employed by man in order to enable himself or his animals to withstand and to endure conditions peculiar to a new environment in which they may be placed.

The influence incidental to a change of environment which may call for such special measures may be quite different for man, for domesticated animals and for wild animals. In the case of the latter, especially, there is a marked lack of knowledge as to what such a change may involve, because, as a rule, the animals' natural habits and the nature of their accustomed environment are but very imperfectly understood.

This lack of knowledge is not a formidable obstacle to man's own change of abode, but, aside from definitely known pathogenic factors which may threaten him, his removal from wholesome, social restraints and from the accustomed sanitary safeguards may increase his hazards in the new home.

The acclimatization of domestic animals is peculiarly free from many of the difficulties mentioned. Their habits are well understood, their optimum foods are known, and psychic or social influences can probably be eliminated from the problem. Disease hazards of a regional character can usually be foreseen and the life of the animals concerned can, to a large extent, be so regulated as to meet most situations.

Yet, in spite of all the advantages enumerated above, the fact remains that the various factors which enter into the making of climate hygienically considered, are after all, applicable only to individual

animals, and will continue to exercise their influence on a race, breed or population which may be implanted on an alien soil. There is much evidence which shows that the imported breed in order to survive at all is bound to lose many of its original characteristics in the process of adjusting itself to an environment widely different from that which was the home of the original stock. In this manner, new varieties may come about which are as well adapted to their geographic locality as the first immigrants were to theirs.

Considerations like the above should make it clear that the process which is still called acclimatization has two phases which, though correlated, are in a large measure distinct from one another. One of these phases pertains to the individual animal, and the other one to a breed or race or even to an entire animal population. In the former case, the protection which man can give to his animals may determine the nature of their fate, but in the latter it is the specific or inherent power for adjustment or accommodation which decides whether the strain shall be permanent or shall eventually perish as such.

The capacity to maintain normal reproduction and to transmit qualities needed in the struggle for existence is the effective means by which an animal, species or variety can acclimate itself in an environment widely different from that peculiar to its home range.

The difficulties which may be encountered in the process of acclimatization or naturalization are usually proportionate to the differences which may exist between the old and the new habitats. As a general rule, they increase as the distance in latitude between the original place of abode and the one to be occupied becomes greater. Differences in altitude may exercise the same influence. On the whole, however, the difficulties met with in acclimatization are less when animals are moved from a warmer to a cooler climatic zone than when the displacement is in the opposite direction.

The greater the differences which are to be met in the change of locality, the more should attention be paid to such safeguards as the ingenuity of man may place around the animals to be moved. The animals themselves must always be carefully selected, and individuals of inferior quality or of manifest unsoundness should not be subjected to any change which is apt to place an unusually great burden on their capacity of adjustment to an unaccustomed environment.

This capacity is normally greater in the younger individuals, although this is by no means a universal rule. For most species apparently, the stage of life when the body has already well progressed in its development and has as yet to acquire its more individual char-

acteristics is the most suitable for the purpose of acclimatization. On this basis, the acclimatization optimum is to be found in animals from half to three-fourths full grown.

The presence or absence of certain individual or racial qualities may exercise an influence by which the fitness for adaptation to a strange climate or environment is materially affected. The smaller breeds and lean individuals, as well as animals with a more delicate skin and fine hair coat, show a greater power of adaptation when brought into a warmer climate than the more bulky ones with a thick integument and heavy hair covering or fleece. The latter more readily accommodate themselves to regions with a relatively low mean temperature and where chilly and damp weather conditions are apt to prevail. Cutaneous pigmentation frequently proves to be an advantage to animals introduced into warmer regions, where exposure to direct solar radiation is a more or less constant feature. The dark-skinned breeds of swine, for instance, thrive in the more southern climates where the non-pigmented breeds have difficulty in maintaining themselves.

The season during which the change of environment is to take place is worthy of consideration. If at all possible, the arrival of the animals in their new home should be so timed that neither the extreme heat or cold of its climate will have to be met. This is more important when the change is to a warmer climate than when a colder one is the ultimate destination.

Many tropical animals tolerate low temperatures quite well if they are adequately nourished and if they are given opportunity to move about in an unrestricted manner. This is well illustrated by the experience of the Philadelphia Zoological Society, which has adopted the practice of putting out-doors all monkeys of value that are suspected of being affected with tuberculosis. These animals are kept in spacious cages, and they not only survive under rather rigorous climatic conditions, but have not succumbed to tuberculosis.

Emphasis has been placed on the need of making the change from one climate to another a gradual one. This happens when animals, in their natural state, change or extend their range. For the domesticated animals, it may also be a more or less ideal method of acclimatization, but the time involved and the means of transportation now employed tend to render it inapplicable on account of economic considerations. However, when grazing animals are moved from higher to lower altitudes, or vice versa, the slow movement in either direction may have its advantages.

The feeding of animals in process of acclimatization should receive the most careful supervision. The rations should be based on the requirements for maintenance only, and the less the food selected differs from that of the accustomed régime the better it will be.

In another chapter, attention is called to the danger associated with poisonous plants for animals foreign to a given range, and this feature must not be overlooked in the management of livestock placed in a strange environment.

The disease hazards peculiar to the region in which animals are newly introduced should be given the most careful consideration. Most of the disasters incidental to a change of abode are attributable to that source, and in accordance with the nature of the disease especially to be feared, special measures of precaution should be applied. This not only pertains to disorders of a microbic or parasitic origin, but likewise to certain non-communicable ones (nutritional disease).

Newly introduced animals should not be required to work for a considerable period. Although freedom of movement is an advantage, the animal at rest is always better prepared to adjust itself to unaccustomed living conditions.

The acclimatization process is further enhanced by sanitary surroundings. Of the utmost importance to livestock under all conditions, they are doubly essential to animals adjusting themselves to the living conditions which the new environment may impose on them.

In the acclimatization of a race, breed or alien species, the safeguards which man can place around the newcomers must be supplemented by inherent qualities of the animals themselves if they are to maintain themselves in a permanent manner. They must possess plasticity and the capacity of transmitting to their offspring the qualities which will enable them to prosper under the new conditions. Among these characteristics an unimpaired power to reproduce is the most fundamental. Even this may not always be sufficient from a standpoint of animal production, as, in spite of normal reproduction, the most desirable racial qualities may become lost under the influence of factors peculiar to the new environment.

The deterioration of a desirable stock on an alien soil is by no means an uncommon phenomenon; it is one of the chief difficulties encountered when in a new region animals of foreign strain are used as a base for the establishment of animal husbandry. The intrinsic disposition to change under different living conditions inherent to all

biologic forms may aid in the preservation of a species, but from an economic standpoint the results may not always be the most desirable.

The changes mentioned above are apt to be most profound when the difference in climate and environment to be met are the greatest. Acclimatization is, therefore, most readily accomplished when the living conditions of the new abode are somewhat similar to the ones under which the animals were previously maintained.

When the new animals are to be introduced into a region having indigenous breeds of the same species, the deterioration of the former may be prevented by crossing the breeds. The crosses thus formed are more resistant to the adverse circumstances to which the new animals may succumb. Although the economically desirable qualities of the foreign improved breeds may thus be partially sacrificed, a resistant strain may be developed, which in the hands of the skillful breeder, may, nevertheless, be transformed into a useful type peculiarly adapted to the region and its climate.

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CHAPTER IX

STABLES AND ENCLOSURES

WITH man's transition from a more or less nomadic existence to a mode of living less mobile in character, the establishment of a more substantial and permanent type of shelter was, no doubt, one of the more important steps on the long road toward a definite form of civilization. And as man began to house himself and to perfect the domestication of his animal possessions, the practice of sheltering livestock was but a natural sequence in the scheme of progress. In fact, domestication means housing (from the Greek δομος=house), and there can be no doubt that the beginning of this process was a common occupancy of shelter by both man and beast, a practice which, here and there, has persisted to this day.

With the advance and refinement of animal husbandry, the housing of animals in special structures, stables, developed into an established practice, and such buildings came to have a place in the exploitation of livestock. As such, they offer many advantages as well as some decided drawbacks.

Among the former we recognize the protection of the animals against the inclemencies of climate, against marauding wild animals and certain insect pests, and the old adage about "locking the stable after the horse is stolen" suggests that even human weakness may have been a factor in the promotion of domestication. The stabling of animals, furthermore, fosters more efficient individual care of the livestock and their feeding. It favors a closer supervision and helps to render the animals more docile. It affords a more desirable place for attendants, as well as animals, for such details in exploitation as milking, and it adds to the convenience under which such operations can be carried on.

The disadvantages connected with the stabling of livestock must, however, not be overlooked. The housed animal is withdrawn from the beneficial effects of the outdoor air, the direct exposure of solar radiation, and the stimulating action of changes in temperature. The feeding régime in stables is apt to deprive the animals, wholly or partially, from the benefits associated with green or other succulent

forage. To a large extent, the stabled animal becomes restricted in its movements and under certain circumstances is condemned to a degree of idleness conducive to the development of such vices as cribbing, weaving and the like. The stable compels animals to live in a most intimate contact with one another and with their body wastes. As a consequence, communicable diseases spread more readily in stables, and the same influence favors the dissemination of external parasites.

The stable and the environment it brings about thus become subjects of concern to the hygienist whose function it is to bring to the indoor animal a maximum of safety without impairing the economic benefits which justify its establishment and maintenance.

The Stable Site.—The selection of the site upon which the stable is to be erected involves consideration, utilitarian as well as hygienic. The former have frequently the most weight in the choice, and economic reasons often prevent the latter from influencing the selection. No doubt, the stable must be placed conveniently near fields and pastures and not so far removed from the abode of attendants so as to preclude the proper supervision and care of the animals concerned. From a hygienic standpoint, the site must, above all, be chosen with regard to freedom of moisture, to the free access of air and light and yet with a view to protection against adverse climatic influences.

The ground upon which a stable is to be built should be well above that of the immediate surroundings in order to promote a free drainage of liquid wastes and to facilitate the prompt removal of precipitation water. Low ground should always be avoided, and the water table should never reach the foundation or the footings of the walls. When topographic conditions compel the use of the low ground as a building site, it must be raised by means of filling or must be rendered suitable by the provision of artificial drainage.

The more pervious soils are always the best suited for building sites, and southern, gentle slopes, underlaid with a gravelly or sandy subsoil, are commonly favored.

The near presence of bogs and swamps is objectionable, as they frequently furnish dampness to the environment and may serve as breeding places for a number of pests and parasites. On the other hand, selecting a building site on the leeward side of a hill or wood may be of advantage in regions having a rigorous climate marked by strong winds. On level plains the planting of trees may be advisable in order to secure a degree of protection against prevailing strong winds. Steep slopes are to be avoided as stable sites.

In the choice of a stable site, consideration must be given to the manner in which the building is to be placed. The direction of the frontage of a stable may vary in accordance with climatic conditions, and the general plan and arrangement of the structure to be erected must also influence the nature of exposure. The problem of frontage for a stable situated within one side of a barn is different from that for one occupying the entire building.

The placing of the building should be such as to assure a maximum of warmth in winter and of coolness in summer; it is always desirable to protect the animals against the more severe glare of the sunlight.

For stables having windows and doors on all sides, preference is commonly given to a placing which gives a northwestern or southeastern direction to their long axis. If this is objectionable for topographic reasons, a north and south direction of the longest diameter is frequently chosen.

A northern exposure is objectionable in many climates, because it is apt to render the stable cold in winter and prevents the entrance of sunlight. On the other hand, such an exposure is apt to materially reduce the annoyance occasioned by the swarms of flies which so commonly detracts from the value of a southern face. For stables built in one side of a barn the southern exposure is to be preferred to a northern one, and if this brings the disadvantage of the glaring light and excessive heat of a midday sun, mitigation may be secured by a suitable planting of trees. Poultry houses are frequently given a southern exposure, the north wall not being used for window space.

Building Materials.—Various materials enter into the construction of stables. They range from the expensive tile, marble and metal of the luxury stable to the sod with which the pioneers sheltered their livestock. It is difficult to determine their relative value from a hygienic point of view. Their properties may be either advantageous or the opposite, according to the demands made upon them and the part which they have to take in construction work.

The essential parts of the stable, such as foundation, walls, floors and ceilings, do not require the same qualities of the building material; also the combination of the various substances used for mortar and plaster are apt to modify the character of the primary materials.

Certain properties of the building materials used in the construction of the walls help to determine and to regulate the relation between the exterior and the interior of the stable.

The degree of porosity of the material defines its heat-conducting

property, its capacity for holding air and water, and this quality is always an important factor in causing dampness or dryness, as well as the efficiency of a structure in the protection against the extremes of climate. The more porous the material, the less will be its heat-conducting and the greater its absorbent properties. Porosity of a building material will thus tend to keep a stable warm in winter and cool in summer, and differences in this quality are responsible for the fact that the same degree of protection against heat or cold may be afforded by a brick wall 1 foot in thickness and a stone wall twice as thick. The effect of porosity may be materially modified by the amount of moisture absorbed. On the other hand, porosity has the disadvantage of favoring the retention of infective micro-organisms and of being an obstacle to cleanliness and disinfection. This defect may be effectively overcome by rendering exposed surfaces impervious by the application of hard plaster and paint or similar substances.

As a non-conductor of heat, wood is always better than brick, stone or metal, but is more apt to present open cracks or imperfect joints which may become receptacles of filth and hiding places for vermin. It is less durable and more combustible than the other materials mentioned. The harder the wood the better does it resist humidity. A coat of paint greatly increases its imperviousness without impairing the advantages associated with its porosity.

Brick varies greatly in its porosity according to the method of manufacture. The softer types of brick are the more porous; the harder varieties are better conductors of heat.

Sandstone and certain grades of limestone are fairly porous, but such types of stone as granite and marble are only slightly so and are therefore good conductors of heat. Unless certain methods of construction are followed, they are rather apt to make a stable cold in winter.

Concrete is a very excellent building material, but it is only slightly porous and when used for the erection of walls a special type of construction should be adopted, if the stable is to be warm in winter.

Iron and steel are used in the construction of the framework of fire-proof buildings and as a reinforcement of concrete. These materials are impervious to moisture and to filth, but are better heat conductors than the other building materials in use.

Mortar is used to join stones and bricks used in construction. It consists of a mixture of which sand, lime or cement, and water are

the component parts. It hardens when exposed to the air, by drying and by the fixation of the carbon dioxide to form carbonates. Its porosity largely depends on the coarseness of the sand, but as a rule, mortar is quite porous.

Details of Construction.—The architectural designs of stables and their general arrangement are often determined by prevailing customs, and commonly they are without special hygienic importance. This is especially true of those to be occupied by only a small number of animals. If, on the other hand, a considerable number of animals is to be housed, the type of building as well as its interior arrangement should not only be planned with convenience in operation as a definite objective, but likewise with a view to permit sanitary conditions to prevail.

Walls.—The foundation or footing of the stable wall, as well as that part which extends from the footing to a foot or more above the grade line, is preferably constructed of impervious material. Concrete is usually preferred for this, although a dense type of stone, such as granite, will also answer the purpose. The minimum degree of porosity of materials of this type tends to prevent the soil water from being carried upward into the superstructure, a feature apt to promote dryness of the stable.

In the cases where for some reason the use of a porous material is necessary, an impervious layer or course of vitrified brick, cement, plaster or even tar paper should be interposed to break the continuity of the capillary spaces within the structure. The absorption of moisture by any porous material used for foundation walls can also be prevented by coating them with cement, plaster, coal tar or asphalt.

The foundation wall should extend for a short distance above the level of the floor, but above that point a wider range in the choice of building material is possible because porosity of the enclosing walls is no longer objectionable, but is a quality to be greatly desired. As already stated, it promotes warmth in winter and coolness in summer, and in stables without special ventilation equipment it permits a certain degree of air exchange.

On the other hand, porosity of the exposed surfaces is objectionable because it may furnish a biding place for pathogenic microbes, and it will permit the absorption of moisture which may render the stable damp and cause micro-organisms to penetrate more deeply into the wall substance.

The ideal construction of the wall above ground is always of ma-

terial quite porous within, but protected outside as well as inside by a layer of impervious material. The most desirable construction is one in which a volume of air remains imprisoned within the wall. This constitutes a special advantage of the wooden stable walls in vogue in this country, in which the upright 2 by 4 or 2 by 6 studding is tightly sheeted on both sides, with or without the further protection of a layer of tar paper. A similar air space should be provided in walls built of impervious stone or concrete if the space within is to be protected against atmospheric influences from without.

All walls within the stable should be smooth for the maintenance of a degree of cleanliness.

Dampness of stables is usually associated with inadequate ventilation or faulty drainage, but in addition to the moisture absorbed by porous foundation material the use of impure water for the preparation of mortar and concrete may also become a factor in its retention. If such water is rich in chlorides or nitrates, those substances may render the walls more or less hygroscopic, either by their own water of crystallization or by that of the chloride of lime formed in the wall substance. These hygroscopic salts also play a part in the deterioration of the building materials used.

Ceilings.—The ceiling of a stable should be so tightly constructed that it excludes the dust from above as well as the air from below. Tightness of the ceiling as well as of other parts of a stable, furthermore, is essential to adequate functioning of the ventilation equipment.

Although concrete ceilings are seen here and there and may be more common in the future, wood will probably continue to be the most frequently used material. By the use of building paper or tar paper under the boards and by the application of paint to the stable surface a ceiling may be made quite impervious. If possible, the ceiling should be so constructed as to provide for an air space between its component layers of boards.

As in all other parts of the stable, projections upon which dust may lodge should be avoided in the construction of the ceiling, and the angle of its junction with the walls should be rounded out in order to preclude accumulation of dust, cobwebs and similar substances.

Floors.—From a hygienic point of view, the floor is one of the most important of the structures which enter into the building of the stable. It is the part particularly exposed to various kinds of contamination and should be so placed and constructed that any

harm which may be brought about by the deposit of body wastes or other infection sources may be reduced to a minimum. Furthermore, it should possess qualities promoting the safety and comfort of the animals occupying the stable.

In no other part of the stable is imperviousness to moisture more essential than in the stable floor. A porous floor soon becomes permeated with organic wastes, and if specific infections or parasitic diseases are present, such a type of floor may become a reservoir for the causative organisms. In addition, such floors are not readily disinfected, thus constituting a definite obstacle to the maintenance of cleanliness.

The floor should be sufficiently elevated above the grade of building site to permit free drainage and to protect the interior against the entrance of excessive precipitation water.

It must be constructed with due regard to the weight and kind of animals to be housed in the stable, and must be substantial enough to prevent damage by cracking, etc. A degree of smoothness of surface is imperative, and the animals should not be liable to injury caused by projecting parts. Resiliency is of value, although it is not always possible to combine this with strength and durability. Though the stable floor must be smooth, it must not be slippery. A slippery floor is always apt to become a source of injury, such as fractures, bruises and strains.

In this country, and especially in the case of farm stables, wooden floors are still common, although they are gradually giving way to those made of better materials. They consist of planks, resting upon stringers, imbedded in the soil, or placed upon joists, the latter arrangement permitting an air space between the ground and the floor. The air space thus formed should be made to communicate with the outside so that a certain degree of ventilation is possible. This not only will tend to prevent decay of the floor, but also has the advantage of promoting dryness of the ground below the stable, a condition not without a certain sanitary value.

A wooden floor suffers more from wear and tear than one constructed of certain other materials. The tramping and pounding by heavy animals as well as the use of tools in cleaning are commonly fatal to wood, and actual decay remains the principal factor in rendering such floors comparatively short-lived. Decay, may, however, be considerably delayed by subjecting the lumber to a process of preservation such as "creosoting," by which the action of destructive bacteria and fungi is materially inhibited.

Wooden floors should be tightly constructed, and it is of advantage to fill the joints with coal tar or asphalt. Yet in spite of sound and appropriate construction, the wooden floor cannot be regarded as a sanitary one because its porosity as well as its liability to decay constitute the means by which certain pathogenic factors are retained, cleanliness is prevented and disinfection is made difficult or impossible.

Stable floors of vitrified brick are not popular in this country, but in Europe this is still a common material. Such paved floors, if properly constructed, may be quite durable, and are certainly sufficiently rough to prevent slipping. However, they are apt to become damaged and to crack under the weight of heavy animals and by the stamping of shod horses. Even when laid upon a concrete foundation they are prone to this damage and when this has come about they are no better than the unsanitary wooden construction.

The wooden floors of this country, as well as the brick ones in other sections, are gradually being replaced by concrete construction. Such floors are impervious to moisture and very durable, although they have the disadvantage of being hard and are apt to become slippery and cold in winter unless special methods of construction are followed. Excessive smoothness may be eliminated by rough surfacing, or by sprinkling the concrete, before it hardens, with coarse sand or a fine iron slag.

The use of a thick layer of cinders under the floor renders it less cold, or the placing of the concrete mixture on a layer of hollow brick, or even common drain tile, is also instrumental in making the floor warmer in winter. As a further means of overcoming the disadvantage of coldness a false floor of planks may be placed over the concrete. Such a false floor may consist of a frame of planks arranged to fit in the stall. If properly constructed, such an arrangement will not only prevent the animals from coming in contact with the cold floor, but it will likewise prevent the accumulation of urine on the floor upon which the animal is otherwise compelled to lie down.

Instead of the bulky, loose floors, built upon a heavy frame, use may be made of loose planks which are held in position by means of iron pegs placed in the concrete and which fit into corresponding holes on both ends of the planks. This arrangement permits the ready removal of the individual planks and constitutes a feature of convenience in repair and in the maintenance of cleanliness.

A more refined method of overcoming the more salient disadvantages of the concrete floor is associated with the use of creosoted wooden blocks or cork bricks. They are especially recommended for

cow stables, their use being confined to the standing platforms. This form of floor construction provides a warm, dry, resilient and comfortable floor and largely does away with slipperiness. The blocks or cork bricks are snugly fitted into a depression left in the concrete and are laid with asphalt joints in order to secure imperviousness and to provide for expansion. Such floors require a certain amount of supervision inasmuch as defective units must be replaced, and an occasional coating with liquid asphalt is essential to their durability.

When concrete is used for the construction of the floor of the cow stable, it is of advantage to build the manger of the same material, and at the same time, provision should also be made for the gutter behind the animals. The concrete manger is described in another chapter, but attention may here be given to the gutter, for it constitutes an important part of the stable. It should be large enough to contain all the manure for a period of twenty-four hours without being filled to the extent that the cows become soiled when lying down. This usually requires a gutter having a width of from 18 to 20 inches and a depth of 8 to 10 inches. The level of the aisle back of the gutter should not be more than 4 or 5 inches higher than the bottom of the gutter itself. This places the level of the standing platform from 4 to 6 inches above that of the aisle.

In the horse stable, the gutter should be a slight depression rather than a distinct gutter, or if such a one is desired it should be made about 8 inches deep and 6 inches wide, to be covered by planks set flush with the floor.

Space and Internal Arrangements.—There are wide variations in stable plans as well as in their final aspects and internal arrangements. Usually the ideas and the financial ability of owners are determining factors. These ideas are sometimes modified by tradition as well as by purely hygienic considerations. The influence of the former, the close adherence to ancestral or archaic forms of construction, may not always give the latter free play. But, on the other hand, we may often witness a fairly workable compromise between tradition, purely business considerations and sanitary qualities.

On the whole, the interior arrangement of a stable can be safely left to the judgment of the practical owner or operator as long as such sanitary needs as ventilation, drainage, lighting and cleanliness have been adequately attended to.

Only a few points in connection with stable planning require mention, because they are of interest to the hygienist as well as to the architect. They are especially associated with the kind of animals

to be housed, although features of a more general nature must also be examined. To the latter belongs the question of space. Height and floor space require consideration. Individual floor space must vary more with the kinds of animals to be stabled than the cubic space of stable as a whole, which is especially influenced by the total number of occupants and by the floor area to be occupied.

Whereas there is a measure of agreement among authors with reference to the area to be set aside for each animal, there is difference of opinion regarding cubic space. In actual practice, furthermore, this diversity of view is still greater, being often complicated by economic considerations.

As stated in the chapter dealing with ventilation, the matter of cubic space within a stable is not nearly so important from a sanitary viewpoint as the volume of air exchanged which may be secured. Yet, the stable dimensions or rather the relation of height to floor space must be somewhat proportionate. The admission of daylight into a stable is more or less dependent on the proportion between the three dimensions. Prevailing climatic conditions also exercise an influence because high stables may become too cold in winter; they are more suitable for warmer climates where they are conducive to coolness. On the other hand, stables which are too low are apt to become too warm and their atmosphere more readily vitiated if the ventilation should become inadequate.

Allowing for local as well as economic requirements, horse stables for less than 10 horses should have a height of from 10 to 12 feet in the clear; for more than 10 and less than 30 horses, a height of from 12 to 14 feet is desirable; stables for more than 30 horses may well have a height of from 14 to 16 feet; and in very large stables, the height may be increased to from 18 to 20 feet.

Cow stables for less than 10 cows should have a height of from 8 to 10 feet; stables for from 10 to 30 cows, from 10 to 12 feet; and in those for more than 30 head the height may be from 12 to 14 feet. In stables intended for young cattle only, the height may range between 8 and 10 feet, in accordance with the number of animals.

Hog houses will vary from 7 to 9 feet in height, and stables occupied by sheep should have a height of from 10 to 16 feet, the number of the occupants being a determining factor.

Poultry houses, commonly built with a shed roof and with the high side facing south, should be, at that point, from 8 to 9 feet high, and on the opposite side from 4 feet 6 inches to 5 feet 6 inches.

The floor space of a stable is occupied by the stalls or stands for

the animals and the cleaning and feeding aisles. They are usually placed parallel to the sides of the stable, although other arrangements may here and there be seen. The floors of the stalls must always have a gentle slope toward the drain or gutter, a drop of 1 inch being regarded as sufficient for the purpose.

The length of a common horse stall will range from 8 to 10 feet in the clear, the dividing partition being from 7 to 8 feet 6 inches in length; the shorter forms permit more of the animals to show, but are less of a protection against injury by kicking. The width of such stalls in this country usually ranges between 4 feet 6 inches to 5 feet for the ordinary type of horses. The larger draft horses may require a few inches more space, and in more pretentious stables a stall width of 6 feet might be provided. Double stalls range from 8 to 9 feet in width.

The partition between the stalls may be of the fixed or the swinging type or bail. The former is preferred because the latter is often a source of injury when animals manage to kick over the structure. Even the safety devices here and there in use do not always prevent such accidents.

The fixed or solid partition should be strong and sufficiently high (not less than 5 feet), and near the head of the animals high enough to prevent the animals annoying one another during feeding. Such partitions are commonly made of wood; concrete may also be used. As they are exposed to considerable wear and tear, they should be substantially built. The rear part of the partitions may be protected by a kicking plate of soft steel, 3½ feet in length and 3 feet in height. In order to permit a more ready circulation of air the upper part of the partition is commonly made of trellis work or grating.

Padding of the partitions is occasionally provided in order to protect the projecting parts of the animals lying against them. This may be accomplished by upholstering with common canvas stuffed with straw, by nailing a piece of heavy felt against the structure or by hanging a fiber or straw mat against the side of the stall. Such structures do not promote cleanliness and in addition require frequent removals owing to the wear and tear to which they are exposed.

Box stalls permitting a moderate amount of movement should be approximately 12 feet square; 7 feet is a suitable height for loose box partitions. These are commonly made of wood panels surmounted by trellis work.

Pens for colts running loose should be large enough to allow from 6 to 70 square feet of floor space per animal.

Cow stalls should be of such length that when a cow is standing in a natural position the heels of her hind legs are at or very near the margin of the gutter behind the platform. This necessitates a stall length of from 4 feet 8 inches to 5 feet 2 inches, measured from the curb of the feeding trough to the gutter, for the larger breeds of cattle. For smaller breeds a length of 4 feet 4 inches to 4 feet 10 inches is enough. In order to accommodate various breeds in one stable the length of the stall platform should vary, the shorter stalls being at one end of the row and the larger ones at the other end. In stables with two rows of stalls built in the manner indicated, the short stalls of one row should be opposite the long stalls of the other in order to balance the stable plan.

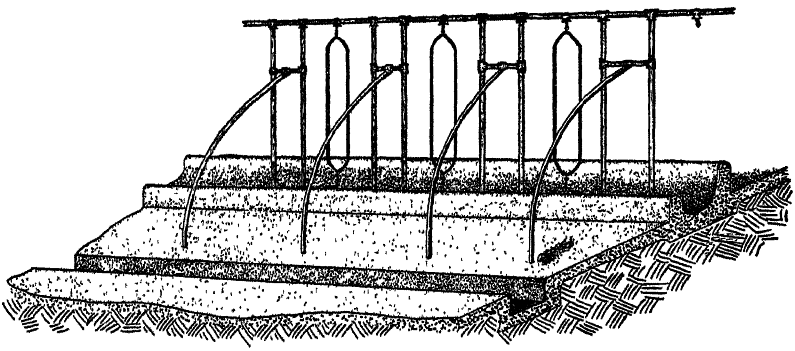

FIG. 41.—A detail of cow stable construction.

The width of cow stalls also varies with the type of animals which occupies them. In a large number of modern dairy stables, the stalls are 3 feet 4 inches in width, usually ranging from 3 feet 2 inches to 3 feet 6 inches. The latter dimension is often regarded as the standard.

In order to remove the danger of cows injuring one another by stepping upon the udder or teats the stalls should be divided by a partition. Such divisions are now usually constructed of bent steel tubing (Fig. 41).

Cow stables for double rows of cows should have a minimum width of 36 feet; those with a single row, 20 feet.

Yearlings kept in pens require about 45 square feet per head; calves up to 12 months of age, from 25 to 30 square feet of floor space per animal, exclusive of mangers and other structural objects.

When swine are confined in a stable, from 35 to 65 square feet per animal should be allowed for brood sows or boars, according to

size, from 15 to 25 square feet for fattening hogs, from 10 to 15 square feet for shoats and from 6 to 10 square feet for pigs. In the case of shoats and pigs it is usually advisable to be a little more liberal in the matter of floor space. The partitions separating the individual hog pens should be from 4 to 5 feet in height, the latter dimension being preferable for the boar's pen.

The farrowing pens should always be provided with a guard or rail fastened to the wall or partition in order to prevent the pigs being crushed by the sows. Such a pig guard should be about 8 inches above the floor and extend an equal distance into the pen.

Folds or pens for sheep should provide a floor space of approximately 15 square feet for each animal and preferably a little more

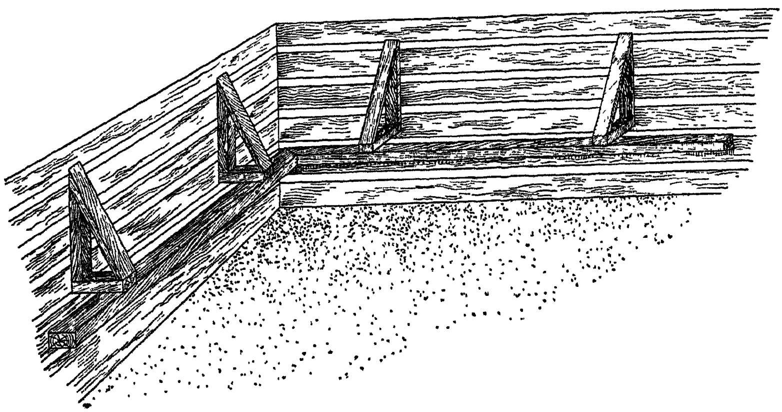

Fig. 42.—A pig-guard rail for farrowing pen.

for the lambing pens. A rack or trough space of from 15 to 18 inches per sheep is required.

Fowls require a floor space of from 3 to 4 square feet per bird. The perches should be removable, and a frame covered with 1-inch mesh wire netting should be fastened under the perches in order to promote cleanliness by preventing access of the birds to the dropping board. The latter serves the purpose of collecting the fecal matter evacuated while the birds are roosting. It should be found in all poultry houses and above all those in which the fowls are being fed during the winter season. The smaller breeds should have about 6 inches perch room and the larger ones about 8 inches. The perches should be from 12 to 14 inches apart, and a space of not less than 14 inches should be left between them and the wall or ceiling.

The laying nests are commonly arranged in batteries against one or two walls. Each nest should be about 12 inches square for the smaller varieties of fowls and 14 inches square for the larger ones. It should have a height of approximately 14 inches and with the bedding in place should provide for not less than 12 inches head room.

Lighting.—For reasons already discussed in another chapter, it is of importance that the habitation of animals be made accessible to daylight, and hence an adequate number of windows must be provided. A sufficient amount of light in stables can usually be obtained when the total window area is from one-fifteenth to one-twelfth of the floor space. The animals should be so placed in the stable that the light entering through the windows will not be thrown directly into their eyes, although this disadvantage may also be largely obviated by placing the windows at an appropriate height.

The windows must be equally distributed over the available wall space of the stable, and their construction should be such that they can be readily opened in order to be used as an accessory means of ventilation, whenever the air exchange requires to be increased.

Window frames should be so made that they cannot become lodging places for dust or filth, and when they are placed sufficiently low to be in reach of passing animals they should be provided with gratings. The latter must be placed flush with the wall and provision should be made for their easy removal so that they do not become an obstacle during cleaning operations.

In the more severe northern climates the use of double or storm windows may be advisable, not only in order to prevent undue loss of heat, but also to do away with the annoyance incidental to the frosting of the windows arising from excessive stable humidity.

The screening of the window space against flies and other insect pests will not only promote hygienic conditions, but will, in addition, assure a certain degree of comfort to the animals. In stables used during the fly season louver blinds to darken the stable can also be resorted to.

Stable Drainage.—Inasmuch as dryness constitutes one of the most desirable qualities of a sanitary stable, adequate provision must be made for the elimination of liquid wastes of the animal body or of water used for cleansing purposes. The wet stable floor and bedding not only contribute to atmospheric humidity and thus place an additional burden upon ventilation, but the decomposing urine likewise is a source of the ammonia which helps to vitiate the stable air. In

the case of certain diseases the urine may be infective, and by its retention in the stable, infection hazards may be increased.

Liquid wastes when not drained away are apt to play a conspicuous part in the soiling of the hair coat and the skin, and in the case of milk cows, this seriously impairs the quality of the milk. The formation of ammonia in the urine deposited and retained in the stable can be held responsible for certain defects of the hoofs of the animals kept in inadequately drained stables. Such diseases as foot-rot, thrush and canker are not uncommonly induced in this manner; the dermatitis of the flexor surface of the pastern of horses, popularly known as "scratches," is apt to arise from the same source.

In the conveyance of liquid stable wastes, use is made of either open or closed drains. The former takes the form of the gutter already described; the latter consists of a regular sewer placed under the floor.

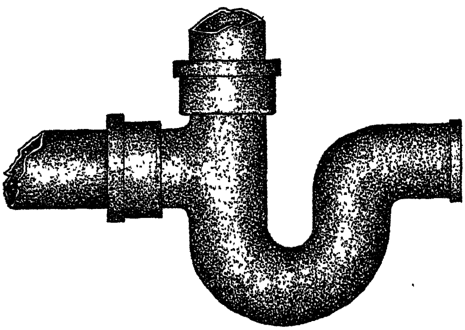

Fig. 43.—A type of "S" trap.

Whatever form of drain is used, it should be so constructed as to preclude seepage into the surrounding soil or into the substance of the floor. All drains must have a sufficient fall. In horse stables a fall of 1 inch in 10 feet is sufficient; in cattle stables a 1-inch drop for every 8 feet should be provided for.

Stable sewers may be constructed of 4-inch glazed or vitrified tile, and they should be given as much fall as consistent with sound and economic construction in order to prevent their becoming obstructed. The sewer inlets may be placed in the bottom of the open gutters behind the stalls or be placed in the floor, which should then be made to slope toward the opening.

In order to do away with disagreeable odors in the stable, the openings should be properly trapped, and in addition they must be protected by grates in order to keep the coarser, solid materials from gaining access to the sewer.

To bring about the closing of the sewer to gaseous impurities, a water seal is usually provided by the common forms of traps ordinarily

used by the building trades. Two principal forms of traps are in common use, the so-called "S" trap and the bell trap. Both are generally made of cast iron. The "S" trap consists of a bent piece of iron pipe interposed at the proper place (Fig. 43), by means of which a certain amount of liquid is retained in the bent portion which shuts off the sewer system from the stable space. In the bell trap (Fig. 44), the sewer opening proper is surrounded by a circular moat in which the liquid is retained to form the water seal. Over the opening a closing piece in the shape of an inverted bell is placed so that its lower edge protrudes for a short distance under the water surface, but does not reach down to the bottom of the moat far enough to obstruct the influx of the sewage under the edge of the bell and into the opening of the sewer.

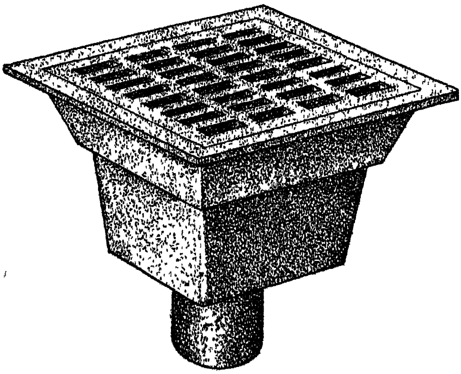

Fig. 44.—A bell trap.

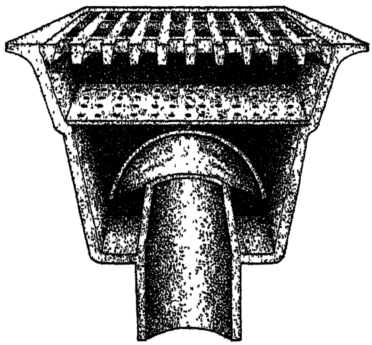

Fig. 45.—Section of bell trap.

Closed sewers must be flushed from time to time in order to keep them continually open. The difficulty of keeping the floor drains below the floor constantly open is a disadvantage of this otherwise ideal manner of stable drainage, and this is warrant for the conclusion that preference should always be given to open drains and gutters within the stable.

Special Features.—Certain details of construction and stable arrangement, aside from those discussed above, must also be given consideration from a hygienic point of view.

Simplicity of the construction and the avoidance of complicated or merely ornamental parts are always advisable. All parts with which animals may come in contact should be smooth and well rounded. This applies especially to door posts, columns and pillars,

ventilation equipment and eating and drinking utensils. Projecting parts are not permissible, and splintered woodwork and protruding nails especially should be promptly eliminated.

The stable doors should be wide (not less than 4 feet for horses and cattle), and their height should be 8 feet more or less. The doors should always open outward and should be hung level so that they do not close automatically. Sliding doors have the disadvantage of becoming a source of injury to passing animals when partially opened. Thresholds should be omitted because they often cause animals to stumble. Doorknobs, bolts and hinges should preferably be sunk into the door parts and posts and must not project from the surfaces.

Simplicity of arrangement should be extended to the means by which animals are fastened. In cow stables, a chain tie around the animal's neck fastened by means of short lateral pieces to rings sliding along posts on each side of the neck is a time-honored method in common use in stables in the rural districts of Europe. It requires some time for tying and untying, which is a decided disadvantage inasmuch as it often gives rise to objection on the part of stable personnel to turning the animals out during the day. The ideal method of fastening animals is associated with the fixed or swinging stanchions (Fig. 46) commonly in use in American stables.

Horses are usually tied to the manger; the principal danger to be guarded against is that which arises from the slackened chain or rope offering the opportunity for the animals to become cast when they step or kick over it. The simplest means of preventing such accidents consists of passing the chain or rope through a smooth hole bored through the manger frame and providing it with a weight on its free extremity (Fig. 25).

Milk rooms and harness rooms are often essential accessories. The former, at least, should be separate from the stable proper. In large cattle stables where abortion disease is a problem, a space should be made available for use as a maternity stable where both normally and abnormally parturient animals can be safeguarded. They should be of sanitary construction throughout and so built that thorough disinfection can be practiced.

Yards and Paddocks.—Economic considerations as well as the manifest benefit conferred upon animals in the open air are responsible for the use of fenced-in spaces, yards and paddocks. In the selection of the sites for such enclosures, preference must be given to ground having a good, natural drainage. A sandy or gravelly

soil is always the best; in the case of heavier soils, concrete pavement or the covering of the ground with a thick layer of sand, gravel, or cinders may be resorted to in order to render them more sanitary. The surface of such enclosures should be fairly level and free from stones and the various forms of refuse and litter which are apt to accumulate in the ordinary barnyard.

Yards and similar enclosures are particularly suitable for horses, cattle and sheep, but for animals like poultry and swine, special precautions are necessary, owing to the feeding habits of this type of

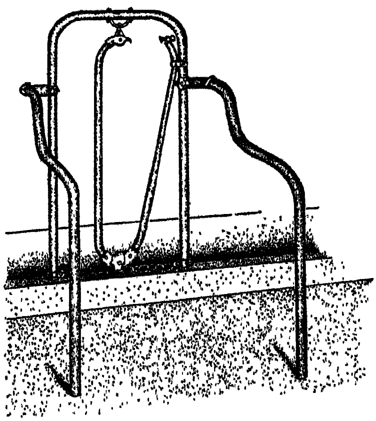

FIG. 46.—A swinging stanchion. (After Hunt-Helm-Ferris Co.)

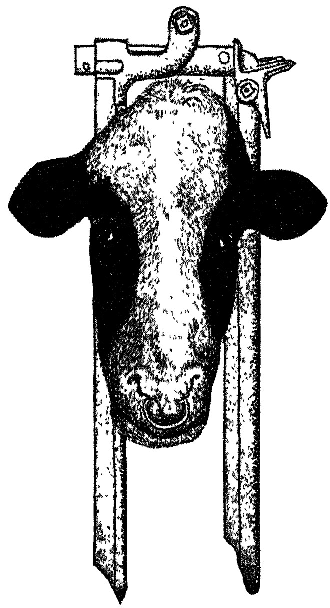

FIG. 47.—A swinging stanchion closed. (After Hunt-Helm-Ferris Co.)

livestock. Such enclosures should not be used for swine less than four or five months of age, owing to the accumulation of fecal matter and the accompanying hazard of food and water contamination by such biologic elements as parasite eggs and the pathogenic microbes of pig typhus, necrobacillosis and other infections. (See chapter on soil.)

Poultry yards continually occupied offer similar hazards, and for this reason provision should be made for an annual rotation of the site used for such enclosures.

Pens, yards and enclosures must be sufficiently large to prevent crowding and to permit free movement of the animals which occupy them. Such enclosures should be provided with substantial fences of woven wire, wood or concrete, high enough to prevent injury to animals which may attempt to escape. There must be no projecting parts, and sharp corners must, above all, be avoided. The presence of shade trees is of marked advantage, and equipment for feeding and watering should be adequate.

When this type of enclosure is more or less continually occupied, some shelter should be provided. This may take the form of a shed placed with due regard to prevailing cold winds, a good plan being to have the shed occupy one or more sides of the square or oblong devoted to yard purposes.

As a rule, a shed consists of a wall tightly built and a roof. The latter rests upon the wall on one side and is supported by pillars or posts, where the shed space opens into the yard. Wood is the material most commonly used in the construction of such a shed.

A shed should be wide enough to accommodate all the animals occupying the yard without undue crowding. Though open on the one side, a few boards fastened to the supporting pillars immediately under the roof are a suitable means of providing a measure of shade.

When yards are to be occupied by animals which also pass part of the time in the stable, it is quite essential to have them in close proximity, even in direct communication with the stable.

The Pasture.—Some of the more salient features of pasture hygiene were mentioned in the chapter on food. A few other considerations should receive attention at this place.

The pasture comes the nearest to being the most natural environment for the greatest number of our domestic animals, and it is quite significant that in those sections where soil and climate are most suitable for growth of grasses and forage plants, animal husbandry has reached the highest development.

Animals at pasture have the advantages attached to free movement in the open air and to a most natural diet, and they are, on the whole, less exposed to certain microbic diseases which are apt to cling to places and enclosures in which they may be confined or concentrated. The favorable influence of a period at pasture on crippled or convalescent animals is well known and may be regarded as evidence of the superiority of this type of environment.

Exposure to certain inclemencies of climate may constitute a disadvantage associated with pasture life, but only to a certain degree,

because such disadvantages are usually compensated for by an increase of vigor and hardiness.

Although it is not always possible to select the type of pasture most suitable to a given kind of livestock, it must be remembered that not all pastures are equally well adapted to all animals. Horses, for instance, do best on rather high and dry land with a soil rich in calcium salts. It seems that under such conditions a better quality of limbs and hoofs is more apt to develop.

Colts of the thoroughbred or allied types do not do well in wet and low pastures, as they are prone to become coarser and more bulky, the limbs develop in a less compact, dry form and the hoof form is apt to flatten.

Cattle, as a rule, do best in damp, shady pastures with a soil producing a luxuriant growth of grass.

Sheep require a close, short, grass land as pasture, which in addition should be fairly dry or well drained.

Swine prefer a more or less damp, shady pasture, with a rather loose texture of soil.

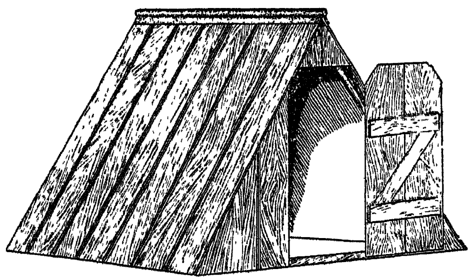

FIG. 48.—Nebraska type of colony house for swine.

With the proper selection of the forage in artificial pastures it becomes possible, however, to somewhat correct the less suitable qualities.

All pastures must be free of poisonous plants, and dangerous bogs should be made inaccessible by suitable fencing. The same provision is frequently advisable in the case of collections of stagnant water, especially with a view to the part these may play in the propagation of the various parasitic diseases. The latter, furthermore, may constitute a good reason for alternating pasturing with crop growing, as during the time when the land is not used for animals, the parasites must succumb for want of a suitable host. Such pasture rotation is especially important in the case of sheep and swine.

The properly rotated pasture is the principal factor in the prevention of parasitism and filth-borne diseases of young swine. In sections where swine growing on an extensive scale is a common practice, the brood sows and their litters are best turned into pasture when the pigs are ten or twelve days old. They should then be given

shelter in the form of movable hog houses, or colony houses (Fig. 48), as they are sometimes called.

All pastures should be properly fenced in. The fences should be substantial and must be kept in a good state of repair. Woven wire of sufficient strength is perhaps the best material used for this purpose, although barbed wire is still most commonly used. The danger of injury associated with the latter may be somewhat reduced by preventing the wire from becoming too slack or by substituting smooth wire for the lower portion. This is of especial importance

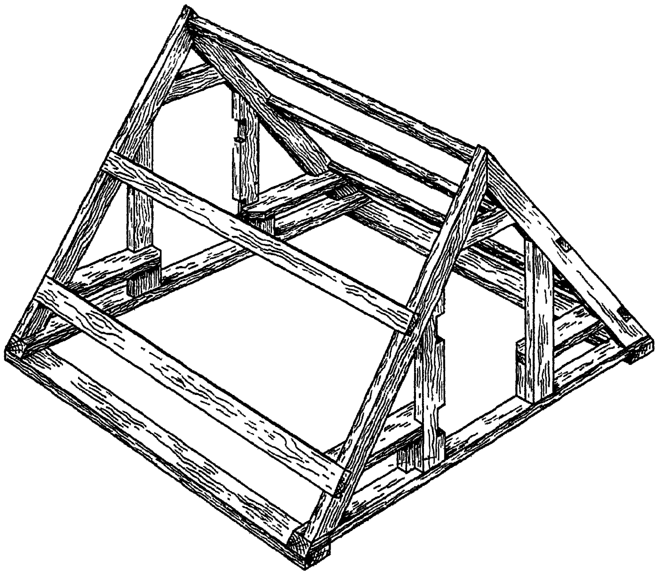

FIG. 49.—Frame of Nebraska type of colony house. (After Wood.)

when young colts are kept at pasture, owing to the tendency of these animals to get their front feet across this wire.

In metal fences it is necessary to have the wire properly grounded in order to reduce the danger arising from lightning. According to the conductivity and effectiveness of the several grounds, a distance of 150 feet, more or less, between the latter will usually answer the purpose. When the fence is supported by steel posts set well into the soil, additional grounds will be superfluous.

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CHAPTER X

INDIVIDUAL CARE AND MANAGEMENT

Animals living under the conditions imposed by domestication are not only dependent on man for sustenance and for an environment hygienically safe, but require, likewise, his care and supervision if their health and well-being as individuals are to be maintained to a degree sufficient for the yield of such energy and substance as may be demanded of them. This individual care and management consists of details pertaining to body cleanliness and comfort as well as to a judicious adjustment of the various forms of livestock to the different purposes of animal husbandry.

The efforts made in care and management vary greatly in extent, ranging between the pampering of the lap dog, the cosmetic artistry of the luxury stable, and the complete absence of any attempt in that direction not infrequently seen in the case of the more inferior type of establishments. Economic considerations largely determine the nature of the attention which animals receive, but it is certain that neglect of all individual hygiene of animals cannot be persisted in with absolute impunity.

Care of the Skin.—The common integument, the most accessible of all organs, not only serves as a mechanical protection to the underlying structures, but also constitutes the chief apparatus by which body temperature is regulated, not to mention its other functions. The fact that it may also become the habitat of many species of parasites may likewise be regarded as warrant that its care has a definite place in the hygiene of animals.

In a large measure this care consists in the maintenance of cleanliness, the removal of exfoliated epithelium, greasy matter, the soiled residue of inspissated cutaneous secretions and the dust and filth which are deposited on the surface and which may find lodgment between the hairs. Such materials, by filling the air spaces normally present in the hair coat, may impair its protective and thermoregulatory functions. In addition, they may become a cause for irritation as well as serve as a medium in which vegetable or animal parasites are most apt to thrive.

In the state of nature and in the case of animals at pasture such accumulations are removed by the action of rain and wind, by the animals rubbing themselves against such objects as trees or posts, by licking and scratching and by rolling on the ground. Horses and mules can be kept quite clean by providing for them a sandy area to roll on after they come from work. The dust bath of fowls accomplishes the same purpose. Fowls and cats regularly make their toilet, and the bathing of birds and other animals is but another instance of the instinctive practice of cutaneous hygiene.

In the domestic animals such natural and instinctive factors cannot be fully depended on, and hence various methods are to be employed in order to secure at least a partial cleanliness of the skin. The application of these methods is largely subject to limitations dictated by economic considerations. There always will be a difference in the amount of care to be bestowed on animals kept for gain and on those which are kept as mere pets, on highly bred animals of fancy value, and on the ones of inferior quality, on the horse which pulls the plow, and on racing or military mounts, where labor costs need not be compared with production results.

In farm animals, especially cattle and swine, grooming is commonly neglected, and only the horse may be the recipient of this form of hygienic attention. On the other hand, in show animals and in certain classes of horses, grooming is a well-established practice and may even be overdone, resulting in the development of irritability, especially in the high-strung, temperamental types of horses.

In the grooming of most animals the brush is always the principal tool; the curry comb should be used only to loosen hair that may have become matted together and for the purpose of cleaning the brush. Both comb and brush should be kept clean, and the former should be especially free of defects and projecting, ragged parts. The use of wiping cloths is recommended as a means of removing the finer dust from the surface of the hair coat. In large stables and establishments mechanical devices operated by small electric motors have frequently displaced the time-honored comb and brush. As electric current is being more and more available in rural districts, its application to grooming equipment may contribute to a better care of farm animals in general, by elimination of labor costs.

Grooming should include attention to the skin and hair coat of the legs as well as that of the body. The use of a wet cloth is often advisable in order to remove the filth which may adhere to the legs.

Mane, tail, as well as the heavy feather peculiar to certain breeds

of draft horses, must also receive the necessary attention. For this purpose it may be required to make use of a coarse comb in order to disentangle the long, heavy hairs, an operation in which the pulling out of the latter must be avoided.

The eyelids, nostrils and lips, as well as the anus and the external genitalia must also be freed of filth, and this is ordinarily best accomplished by the use of sponges or wet cloths. The attention of the groom should be particularly directed to the need of a periodic cleansing of the interior of the sheath in stallions and geldings, and it must not be forgotten that, in some of these animals, small accumulations of a fatty secretion in the anterior portion of the urethra may require removal.

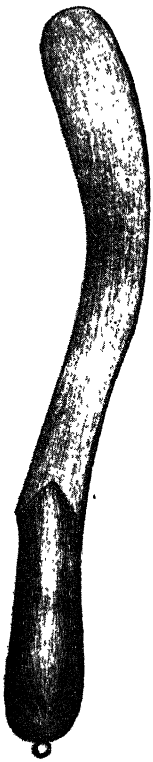

Fig. 50.—Sweat scraper.

Horses wet with sweat, or as a result of exposure to rain or snow, should be dried by the use of the so-called sweat-scraper (Fig. 50), a curved, wooden blade, by which the water may be pressed from the hair coat. The completion of this drying process by friction with wisps of hay or straw is a common practice among grooms.

Cattle also respond to good grooming and, especially in the case of milk cows, it has a direct bearing not only upon health and productiveness of animals, but also upon the quality of the milk. Cows should be groomed before milking time, and the udder, and that part of the body which is placed directly over the milk pail, should be somewhat moistened by means of a wet cloth in order to prevent as much as possible the scaling of the epithelium during the collection of the milk.

Grooming is difficult, if not impossible, to apply to sheep, and only the surface of the fleece can at best be freed of the coarser filth. In swine, grooming is usually confined to show animals only.

It frequently becomes necessary to have recourse to the washing of animals in order to secure the desired degree of cleanliness. This method of cleansing must be periodically applied to the udder and the external genital organs. Under certain conditions, the washing of the entire animal may, however, be advisable.

When washing is to be resorted to, the water should be tepid. If the entire body must be washed, special precautions should be taken to prevent the animals from chilling; for this reason, this method of cleansing is almost entirely confined to the warm season.

Though the use of soap is not always necessary, a good neutral soap facilitates the process and can do no harm. It must always be thoroughly removed by rinsing with clean water. After being washed, the animals must be dried; the sweat-scraper and friction with straw or hay will be helpful for this.

In certain climates and under certain conditions the bathing or swimming of the larger animals is sometimes permissible. For this purpose, the water must have a temperature of not less than 65° F., and animals in a heated condition or immediately after a meal should not be treated in this manner.

The bathing of sheep is practically confined to the so-called "dipping" as a measure for the prevention and cure of scabies, although it has also been used as a means of freeing the fleece of filth immediately before shearing time. The long period necessary for drying is, however, a serious disadvantage which may well be considered.

Swine are often provided with a pool in order to find relief from excessively hot weather. Owing to the fact that such pools may at the same time serve as a source of supply for drinking water and a depository for the excreta, their use may be seriously objected to on sanitary grounds. The use of a spray or sprinkler should, at any rate, always be preferred.

Care of Hoofs and Claws.—In the ungulates living in the natural state, the wear and tear of the hoofs is so balanced by the horn growth that the locomotor apparatus is automatically maintained in a mechanically correct condition. It is otherwise in many of the horses and other animals kept under the conditions imposed by domestication, when confinement, labor, the nature of the ground to be traveled over, and the practice of shoeing tend to disturb the balancing factors mentioned.

In all animals in which horn growth is not compensated by abrasion, hoofs and claws must be subjected to special care, because not only the quality of the hoof itself is involved, but in a secondary manner changes in articular levels may seriously impair the locomotor efficiency and value of the animal.

For the unshod hoof a moderate amount of exercise is the most valuable factor operating in its preservation. However, in the case of colts pasturing on soft ground, it is not amiss to examine the hoofs

every month or two, so as to be prepared to correct whatever faulty conditions may be found to be present.

When animals are stabled, the periodic inspection and the correction of defects are of still greater importance, and these should be attended to not less than once a month. Not only horses, but cattle also, should receive this attention. It is more particularly necessary with herd bulls, if such animals are to remain sound in their legs.

In trimming the hoofs of horses, the outer edge of the compact horn of the wall can be trimmed down so that the lower margin is made to occupy the same level as the horn of the sole where this joins the white line. The outer edge may be rounded by means of the rasp, but the face of the wall should never be subjected to trimming, rasping or abrasions of any kind. The horn of the frog and sole need not be interfered with, as the ordinary wear and exfoliation will readily keep the structures within their proper form and volume.

The thinning of the bars is apt to weaken the quarters and hence is objectionable. At the most, the lower edge of the bar may be trimmed down far enough to occupy the same plane as that of the weight-bearing surface of the horny wall.

The systematic care of the horse's feet further requires that they should be inspected daily for the presence of foreign bodies such as nails and pieces of glass, the penetration of which is apt to give rise to serious damage or even to dangerous septic processes.

The shoeing of horses is necessary to protect the foot against the excessive wear and tear incidental to the performance of whatever duty may be required of the animals. Shoeing must be regarded in the light of a necessary evil, and hence, in colts, it should be postponed as long as possible; it may even be omitted in the case of horses used for field work on soft ground. The shoe always interferes with the mechanical functions of the foot and in consequence with its blood circulation and nutrition. For the shoeing of horses, the skill of the best artisan available is required, because, to a large extent, the value of the horse lies in his hands. After the removal of the old shoe, the excessive hoof horn must be carefully trimmed away in order to restore normal levels, a process from which bars, frog, and sole should be exempted. The new shoe must be properly fitted to the trimmed foot. A level, fullered shoe, without caulks, is to be preferred unless the nature of the labor to be performed upon smooth, or slippery pavements, demands that the latter be used. Should this be the case, the use of toe caulks, by which the shoe is maintained in horizontal position, is to be recommended.

In driving the nails, care must be taken in order to avoid the penetration or even pressing of the sensitive parts; after the nails have been clinched, all rough points must be smoothed off by means of the rasp. If horses have to be used on icy pavements, the use of sharp caulks is an imperative protection. Removable caulks offer particular advantages for this purpose.

During dry seasons and in very dry climates, or when horses are continually kept in the stable, the hoof horn may dry to the extent of becoming brittle and inelastic. Such a condition may, to some extent, be prevented by the use of any bland oil or grease periodically applied to the feet by means of a brush. The excessive loss of moisture from the horn can thus be materially delayed. If the hoofs have already become too dry, the use of a soaking bath should precede the application of the grease.

Of importance to the preservation of the hoof-horn is the condition of the stable floor upon which the animals have to stand. Wet, foul stables commonly promote the maceration of the horn and facilitate the subsequent invasion by micro-organisms, resulting in such morbid conditions as thrush. Clean stables and well-drained buildings will, to a large extent, prevent this evil. In stables in which a filthy condition usually prevails, the application of such substances as tar to the sole may be plainly indicated.

Clipping.—Under certain conditions the removal of the hair coat is a measure of hygienic value. A regular practice in the case of sheep, it is less common for horses and cattle. Occasionally it must be resorted to as an imperative preliminary measure when certain skin diseases have to be managed.

As a result of the removal of the hair coat, the elimination of body heat is substantially increased, and this heat loss must be compensated for by an increased metabolism and heat production. This process is reflected by a greater utilization of fuel and hence by an improved appetite as one of the first and most manifest results of clipping. In certain animals this is followed by improvement in body vigor and by an actual increase in the body weight. The recently clipped animal should, therefore, receive an increased ration in order to enable it to compensate for the greater degree of heat elimination.

Clipping facilitates grooming and promotes cleanliness. Clipped animals dry better and in a shorter space of time, if they become wet, than unclipped ones. To a large extent clipping prevents the so-called "after sweating" frequently seen in work horses with a heavy hair coat placed in close stables after they come in from work

in a heated condition. This "after sweating" is probably more apparent than real, because sweating usually ceases with the termination of muscular exertion. In reality it constitutes a delayed drying in a humid atmosphere and apparently its prevention is more a ventilation problem than an object of cutaneous care. However that may be, the clipping of animals so exposed often becomes a measure of hygienic value.

It is preferable not to remove the heavy hairs at the fetlock, the hair within the ears and the tactile hairs of the lips.

Clipped horses must be protected against chilling for some time, and when they are placed in cold, drafty stables the use of blankets is quite desirable. Clipping is accompanied by the disadvantage of rendering the animals more susceptible to the annoyance by flies and other insect pests, and it is apt to cause the hair to become thicker, more rigid and somewhat staring.

The clipping of cattle is less commonly practiced and may be entirely confined to the tail as a means of promoting the cleanliness of the parts. It may prove of distinct value, however, in the case of calves with too heavy hair coat and as a means of dealing more efficiently with lousiness.

Blankets.—The blanketing of animals is indicated during cold and wet weather, during the period in which the hair coat is changed or immediately after clipping. Animals occupying drafty stables or when in transit in vessels or railway cars may also profit from being covered. It is also practiced in order to afford protection against insect pests and as a measure for promoting cleanliness. The prolonged use of blankets also appears to have some influence favoring the development of a fine, silky coat of hair. Blanketing is, however, not without certain disadvantages, as the habitual covering of the animal body may render it more susceptible to adverse external influences when the blankets are removed.

Blankets vary in weight and texture, according to the influence against which the animal is to be protected. During very cold winter weather a duck blanket lined with flannel may be required, whereas for the protection against flies and dirt a mere net or thin muslin may be found to be quite sufficient.

During wet periods in climates in which persistent, cold rains are apt to prevail, rubber, oil-skin or other water-proof materials are sometimes used as coverings for the animal body. In such cases provision should be made for a sufficient air space between the covering and the skin in order to prevent interference with proper heat elimina-

tion. Water-proof blankets should be removed immediately after the animals enter the stable.

Bedding.—Stabled animals should always be provided with suitable bedding. A clean, soft, litter promotes comfort and cleanliness, and has a decided sanitary value. Bedding also serves to prevent slipperiness of the stable floor, which is an important factor to be considered with concrete or asphalt floors.

Bedding may be chosen from a considerable variety of materials. The more commonly used ones are the straws of cereals and certain legumes, leaves of trees, pine needles and tan-bark; in lumber districts, sawdust is ordinarily used for this purpose. In countries in which peat is plentiful, this material in the form of peat moss may be used as bedding.

Whatever material is selected, it must be dry and free from any ingredients which are liable to endanger the health of the animals concerned. Molds, fungi, pathogenic microbes as well as poisonous plants should, as far as possible, be excluded. It must be provided in abundance, especially for young animals for which the impervious stable floors are frequently too hard and too cold. Certain disadvantages often ascribed to such floors can sometimes be attributed to a mere lack of bedding.

The presence of a substantial layer of resilient material under the hoofs and claws of the larger animals is always desirable, as concussion incidental to the contact between the feet and the stable floor may be instrumental in inflicting injury to the feet as well as damage to the floor.

Material used as bedding should not be too long. Young or crippled animals may get themselves entangled in such material and injure themselves by falling. Short bedding has the additional advantage of permitting the more ready removal of wet or soiled parts.

Soiled bedding must be removed at regular intervals and be replaced by fresh, dry material. Not only does this promote cleanliness of the body surface, but it is also required because of the putrefactive processes which are apt to follow in bedding soiled with the excreta. The atmospheric impurities in no small degree arise from gases formed in this process of decay, and soiled bedding retained in a stable may, under certain circumstances, become a reservoir of microbic causes of disease. If the stable is not continuously occupied it is proper not to cover the floor immediately with fresh bedding, in order to permit the floor to become dry.

In cow stables the bedding should not be changed within an hour

before milking time so as to prevent the dust arising in consequence of this procedure from becoming a factor in the contamination of the milk.

The bedding must be changed at least once a day in horse and cattle stables. In hog pens once or twice per week is ordinarily sufficient; in sheep pens it is often customary to permit the bedding to remain during an entire season. The latter practice, however, must be regarded as questionable from a sanitary point of view.

In stables used for recumbent, sick or crippled animals the substitution of sand for ordinary bedding may be urged as a means to prevent decubitus.

The Use of Animals.—Although nutrition, environment and the general care of animals are hygienic factors of fundamental importance, consideration must also be given to features more especially associated with the purpose for which livestock is being maintained. Although in a measure less essential than the occupational hygiene of man, there can be no doubt that in the care and management of the domestic animals, the living conditions determined by their exploitation must be safeguarded by attention to certain details upon which their health and well-being are to a large extent dependent.

Draft Animals, Carriage Horses and Mounts.—Horses should not be used for heavy and intensive work at too young an age. Farm horses may gradually be accustomed to light work beginning with the third year, and most of the heavier draft breeds can be used for harder work from the fourth year on. For very severe work, however, it is doubtless better not to use horses under five years of age, because such animals have not yet reached the adult state.

The more slowly developing coach or light harness horse can be used for light service at the age of four and a half years, but should not be put to prolonged, exacting work until after the completion of the fifth year, and in most cases it is advisable to use the animals sparingly until after the sixth year. The same general rule should apply to saddle horses, although an exception is frequently made with race horses, which are apt to be trained at the age of two years or even less. That such practices are hygienically faulty cannot be doubted.

Oxen may be used for draft purposes after their third year, but exacting efforts should not be demanded of them before they have reached their fifth year of age.

Imposing hard and prolonged labor upon animals when they are young and immature, when their supporting structures are as yet

plastic in character, is commonly conducive to the initiation of morbid processes in bones, joints, tendons and ligaments. Such diseases as spavin, ringbone, splint, bursites, tendovaginitis, curb, interstitial myosites and similar defects are not infrequently the result of the excessive wear and tear of structures which are still in a more or less incomplete stage of development.

Over-work and inordinate exertion must be avoided in animals at any age, and if at all possible more than ten or twelve working hours per day should not be demanded. In labor performed at a gait faster than a walk the load to be moved should be materially lessened, and a similar rule is, in a measure, also applicable to horses used under the saddle.

Animals at work should be permitted brief intervals of rest during the performance of their task. In most cases a repose of from a quarter to half an hour for every three hours of effort should be granted. If at all possible, two hours for horses and three hours for oxen should be allowed for the midday meal.

Excessive exertion may be followed by cardiac and pulmonary impairment, but most commonly it is some part of the locomotor apparatus which becomes damaged as a result.

On the other hand, hygienic considerations demand that animals be not condemned to absolute idleness, and adequate opportunity for free movement in the open air should be given during periods when they are not in actual use. Prolonged inactivity causes the animals to become soft and flabby, may result in defects of the locomotor apparatus and is always a factor in the acquisition of such vices as cribbing, wind-sucking and weaving.

Harness, Saddles and Equipment.—Horses, draft animals and those used as mounts must be safeguarded by the proper construction and adjustment of harness, saddles, and other equipment. The load to be drawn or borne must be in the proper proportion to the type and size of the animal used and the nature of the road to be traveled.

In all wheeled vehicles or implements, the pole, if one is used, must be sufficiently long to provide for an adequate amount of space so that the animals may not be injured by contact with parts of the vehicle during the descent of hills or when the speed of travel is slackened. The foremost part of the pole should be at the level of the shoulder joint, a position involving the least liability to injury from that source.

In hilly sections, wagons should be equipped with suitable brakes;

the use of breeching harness is always advisable to protect the upper part of the neck against chafing and undue pressure as well as for the relief of the strain on the front legs.

The use of springs (horse savers) interposed between the load to be drawn and the shoulders, in order to break the shock incidental to uneven roads and at the beginning of the pull, is commonly advantageous.

The proper fitting and adjustment of the harness is an important factor in the hygiene of the work horse. Injuries attributable to harness arise, as a rule, from pressure and friction. If pressure is concentrated upon comparatively small areas of the skin or continued for a considerable length of time, the capillary blood supply of the parts is interrupted, the lack of blood necessarily suspending the nutrition of the tissues. This may give rise to a mere reduction in the resistance to microbic influences or may result in tissue death, as exemplified by the so-called "sit-fast" arising from saddle or collar bruises. The harm done by friction is of a purely mechanical nature. The tissues of the skin become abraded, the hair disappearing first, the epidermis next, and the exposure of the derma follows. The irritation and intercurrent infection in either type of injury are expressed by inflammatory processes leading to connective tissue proliferation, cicatrization and tumefaction.

Although friction and pressure must be regarded as the primary causes of harness and saddle bruises and sores, certain conditions intrinsic to the animal itself are also apt to play a part. This, for instance, is the case in horses not accustomed to work for some time, which are spoken of as being "soft." The "soft" horse must be used with more than ordinary caution, if harness injuries are to be avoided.

The principal attention, however, to be given to the fitting of harness is with a view of reducing to a minimum the harm caused by pressure and friction. The effects of pressure may be reduced by selecting a collar which permits the actual contact to become distributed over as large an area as possible. The contact of the collar with the body of the pulling horse should cause a pressure of equal intensity from withers down to the breast at the level of the shoulder joint and including the anterior edge of the scapula. As this area varies in shape in different animals, the collar must also show certain variations after it has become adjusted.

The structure of collar and hame should be sufficiently rigid to distribute the collar pressure evenly over this entire area, and yet

the collar itself must be plastic and soft enough to adjust itself to the contours of the region. A collar which once has become "moulded" to a certain shoulder should not be used on other animals, as only in rare cases will two shoulders be of precisely the same pattern.

A sufficient amount of space must be allowed for the crest of the neck, which should never become pinched. The collar must be deep enough so as to avoid pressure of the vessels and other structures of the lower part of the neck. Where the collar rests upon the crest of the neck, the bearing surface should be of sufficient area to prevent damage to the skin underneath.

Correct apposition of the collar against the shoulder not only distributes the pressure evenly over the entire available area, but it also has a tendency to reduce the effects of friction, even if motion between the two surfaces cannot be entirely eliminated. This is likewise accomplished by providing a smooth surface where the collar comes in contact with the skin. For this reason, a clean collar surface free from incrustations of filth and sweat offers some decided advantages. Collars of which the inner surface has become creased, wrinkled or otherwise damaged should be rejected.

The use of so-called "sweat-pads" or false collars should be avoided if at all possible. Their bearing surface is always more or less rough, and their absorbent properties causes them to retain moisture so that they bring results somewhat equivalent to those of a poultice. The continued presence of moisture under the collar predisposes to shoulder galls, as under its influence the superficial epithelium of the epidermis becomes macerated and apt to be removed by friction.

For oxen, single yokes are to be preferred to double ones, and the padding of the parts which come in contact with the skin is recommended. The other parts of the harness should have broad, smooth surfaces wherever leather and skin are in more or less intimate contact.

Some care must be exercised in the placing of the bit in the horse's mouth. In young horses the mouth is usually tender and sensitive, and unless the animal concerned is abnormally difficult to manage the ordinary snafflebit will answer the purpose. A solid bit is apt to bring too much pressure to bear upon the tongue and the interdental space. The severer forms of bits should be rejected unless an extremely hard mouth or an otherwise uncontrollable viciousness renders their use imperative. For horses used under the saddle, curb bit and bridoon are recommended. The bit should hang neither too high nor too low

in the horse's mouth, the correct position being about the middle of the interdental space. The check rein as well as the blind bridle should be rejected as unnecessary sources of discomfort to the animals.

In the hygienic aspect of the saddle, both the horse's back and the saddle itself must be given consideration. The former shows a marked range of variations, and in the selection and breeding of saddle horses more attention to this feature would in itself reduce the number of mounts temporarily rendered unfit for service on account of saddle damage. In one of the forms most predisposed to saddle injury the withers are high and markedly crested, the contour of the back itself being more or less concave (sway-back.)

The short form of the back is the most desirable and especially so if this pertains to the lumbar region. As a correlation to short loins the musculature of the back is usually well developed, which in itself offers an adequate carrying surface. The width of this area is further enhanced by a pronounced costal curvature, which is especially desirable from the eighth to the seventeenth ribs, as these structures offer the principal support to the weight to be sustained.

The spinous processes of the vertebrae and their ligamentous covering must never be pressed upon by the saddle, however light this pressure may be otherwise. The objection to high-crested withers is justifiable for this reason, as such parts are prone to become pinched and injured unless saddles of special constructions are selected. On the other hand, low, thick or rounded withers render it difficult to fix the saddle adequately, and this is liable to cause too much lateral motion.

In the selection and fitting of the saddle, care should be taken that the supraspinous ligament and the structures covering it remain perfectly free and unburdened under the rider, no matter what position these factors may assume in relation to one another. A free space of not less than two inches should always be maintained between the withers and the arch of the saddle. With this in mind, allowance must be made for the fact that in new saddles the padding is apt to "settle" slightly under the pressure of the weight it has to support,

The bearing surface of the saddle must be suitably padded and in even apposition to the corresponding area of the back. The use of a saddle blanket, especially a felt one, is of advantage, not only as a protection against saddle injuries, but also because it permits the saddle to become more firmly adjusted without drawing too tight a girth. But it should be remembered that saddle sores may be caused by folds and creases in the blanket, and care must, therefore, be taken

that this part of the equipment is smoothly and properly placed. Saddle blankets should always be unfolded when not in use and thoroughly dried, to be folded again before placed under the saddle.

The sidesaddle, used by women, is objectionable because of the unequal distribution of the weight on the bearing surface of the back.

The means of fastening animals in the stable may on occasions play a part in causing injury to them. The methods of tying animals show considerable difference in the various countries. In horses, either the halter or neck strap is most commonly chosen for the purpose. From a hygienic point of view it is advisable to select substantially made equipment so adjusted that the animals cannot free themselves. The fastening rope or chain must be of such a length that the animals cannot become cast by placing their legs over it. Better still is some arrangement so that the slack is taken out of chain or rope. Passing the rope through a wide ring or hole in the framework of the manger and fastening a counterweight to the free end accomplishes the double purpose of stopping the horse when it backs away from the crib and keeping the rope or chain slightly taut, no matter what the position of the animal may be (Fig. 25).

For the fastening of cattle, the loosely suspended and anchored stanchion now universally in use is the most suitable means (Fig. 46).

All fastening equipment must be so made as to permit a speedy and ready securing and release of the animals.

Dairy Cattle.—Under the effects of forced milk production and breeding, a large amount of substance is withdrawn from cows, and in consequence the feeding of such animals must be so regulated that the general state of nutrition does not decline on account of the continuous drain to which the body is subjected.

Likewise, it is hygienically imperative to provide for an interruption of from four to six weeks between one lactation period and the one following in order to permit depleted reserves to be restored and also for the purpose of enhancing fetal development. This "dry" period preceding parturition is not only advisable from a hygienic viewpoint, but from an economic one as well.

In addition to adequate supervision of nutrition, the care of the udder constitutes an important part of the hygiene of the milk-producing animal. The more highly developed and the more functionally active the mammary apparatus is, the more liable it is not only to specific infections, but to mechanical injury as well.

The etiologic factors of mammary infection are commonly introduced through the teat canal and milk cistern. This mode of entrance

is greatly facilitated by unclean and inadequate practices of milking. When a milker leaves a certain amount of milk in the milk cistern and teat canal and permits a drop of milk to remain suspended from the tip of the teat, he establishes an unbroken path which microbic agents can follow into the interior of the gland. By mere continuity of this most excellent culture medium the mammary parenchyma may become subject to microbic invasion. The possibility of such an avenue of infection should always be an incentive to scrupulous cleanliness in the collection of milk and to a practice of milking which leaves no milk in the cistern.

Not only as a means of producing better milk, but also in order to protect the udder itself, the latter should be cleaned before and after each milking. In order to prevent infection and mechanical injury, care must be taken to prevent wounds, abrasions and bruises of the udder. Injuries of the kind may be due to the animals being closely crowded in the stable and from the presence of such rubbish as detached pieces of barbed wire and glass in the yards occupied by milk cows.

Animals with infected udders (garget) should not be tolerated in stables where cows with sound udders are being housed; precautions must be taken to prevent the hands of the milker or the cups of the milking machine from becoming vehicles of infection. An infected udder, therefore, should always be milked last of all, the milk collected rendered innocuous by sterilization and the hands of the milker subjected to a thorough washing if not disinfection.

Wool-producing Animals.—In the individual care of wool-producing animals especial attention must be paid to the prevention of the parasitic diseases of the skin (scabies). The fact that prolonged exposure to rain may also have a deleterious effect on the fleece must also be kept in mind. As a general rule, sheep adequately fed should be kept in the open as much as possible, with a shed provided for shelter during severe weather.

In a few instances, wool production may be interfered with by a habit of sheep of pulling and even eating their own wool as well as the wool of their companions. Not only is such a habit destructive to the fleece, but it is conducive to the formation of balls of wool in the stomach. The habit may be an indication of a nutritional deficiency to be corrected, although, like in many of the vices of the sort, mere imitation may also play a part. The vice of wool-pulling is most prevalent in sheep kept in close confinement and tends to disappear when the animals are turned out to graze.

The shearing of sheep should preferably be done when the weather is mild and stable, although in the case of well-fed animals, the removal of the fleece is usually well tolerated. The use of close, warm stables after shearing must be cautioned against unless ventilation facilities are adequate, because sheep are notoriously susceptible to the influence of excessive heat and humidity.

Wounds and abrasions incidental to shearing operations must receive prompt attention, and laborers engaged in the work should be supplied with a mild solution of iodine (in glycerine) to be applied to the wounded part whenever an occasion arises.

Meat-producing Animals.—Animals kept for the production of meat and fat require a careful supervision of the diet, and all dietary errors which may interfere with the appetite and digestive functions must be scrupulously avoided.

Especial attention must be given to the ambient temperature inasmuch as heat elimination in fat animals is always reduced on account of the subcutaneous deposits of adipose. The heavy rations supplied to such animals tend to favor heat accumulation, and when heat production is further increased by their being subjected to muscular efforts, excitement and to the effects of a hot and close atmosphere, the results may readily become fatal (swine in transit).

Animals in process of fattening are best kept either in a cool stable or in paddocks in the open air, provided with a covered space to protect them against inclemencies of the weather.

Breeding Animals.—The reproductive functions of animals are to be restricted within certain limits. In the female this limitation is an automatic one on account of the gestation period, although even in those animals in which the gestation period would permit two pregnancies per year, it is commonly advisable to restrict this to only one, if reproduction is to be extended over several years.

In the male, sexual activity should be held under a measure of control. In stallions the number of permissible services varies with the individual qualities, but as a rule, the stallion should not serve more than twice per day, and in the case of young animals, five services per week should not be exceeded.

As a rule, the number of from fifty to sixty mares per stallion and per season should not be exceeded, although in certain cases their number has been increased to seventy or eighty without any apparent unfavorable results.

In cattle herds in which breeding is extended over the entire year, one hundred cows per bull can be allowed as a maximum number, but

in establishments where breeding is confined to only a few months this number should be reduced by a third or half. This applies to adult bulls, but the use of younger ones should be still further restricted.

Young rams should be used not more than twice a day and may breed about forty ewes during a breeding season, extending over a period of from four to six weeks. Adult males during a similar period may breed from sixty to one hundred females, their daily service being limited to from four to six ewes.

In swine from twenty to thirty sows are allowed to be bred to each boar during a limited breeding season, but when this period is drawn out over the entire year, the number may be doubled.

Animals must not be utilized as reproducers when too young. Stallions should not be used before the third or fourth year, and mares not until they are more than four years of age. Bulls under one and a half years of age and heifers under two years should not be bred. For rams, these limits should be fixed at from one to two and a half, for ewes two years, for swine from one to one and a half years.

In many instances these limits are exceeded with impunity, but in general the use of immature breeding animals involves both deterioration in the parent and weakness in the offspring; similar consequences may come about as a result of excessive breeding operations. In stallions such unfavorable results may to some extent be obviated by the practice of artificial impregnation.

Attention must also be given to the prevention of injury during copulation; this should include proper regard to the size and strength of the animals to be mated, the hobbling of irritable mares, the avoiding of slippery floors or pavements, etc.

A good, nutritious diet of the sires during the breeding season is of prime importance, but this must not result in the fattening of such animals. An adequate amount of exercise will largely prevent this; the practice of putting stallions to work when not in actual service is sound and has an excellent effect on their vigor and potency. In the males of the other species set aside for reproduction, exercise at pasture or in paddocks is a measure of distinct hygienic value. Lack of opportunity for free movement is conducive to impotency, and the vice of masturbation, common in certain stallions, is often traceable to the same cause.

Pregnant females must have access to a sustaining ration without being fattened. For cows the ration is often reduced for some time prior to parturition in the hope that the restricted diet may lessen the hazard of parturient paresis. Regular and judicious exercise is indi-

cated for all pregnant females, and this pertains to the entire gestation period. On the other hand, such animals must not be used for severe, exacting labor, and of course, all hazard of mechanical injury must be removed.

Prudence dictates that parturient animals be kept under a more or less constant supervision so that aid may be given when needed and accidents be prevented. If parturition does not take place in the pasture, such females must be provided with a roomy stall. The cleanliness of such places is an imperative prerequisite. Premature and unskilled meddling with the parturient function should always be avoided.

The new-born animal is to be freed from the mucoid, yellow material with which it is covered by friction with some soft hay or straw and be so placed that the dam may complete the toilet of her offspring in the manner dictated by her instinct. Above all, the young animal must be placed in clean surroundings and, if possible, be protected against the more severe climatic influences.

Animals in Transit.—The transportation of animals by rail or by water exposes them to highly abnormal living conditions, which tend to become more potent for doing harm as the length of the journey increases. It is, therefore, hygienically essential that consideration be given to their fitness and preparation unless the journey to be made is a short one or the animals concerned are transported for immediate slaughter. Even in the latter case, fitness and preparation will prove to be important factors in determining the degree of "shrinkage" to which animals may be subject in the course of a journey.

The first requirement to be made of animals to be moved is freedom from diseases, especially those of a transmissible character. The extensive movements of livestock and the rapid means of transportation afford opportunities for the dissemination of many microbic diseases. Such movements, therefore, require constant and unrelaxing supervision and attention on the part of livestock sanitary officers, common carriers and persons engaged in the traffic.

To what extent the animals to be moved require special preparation is largely dependent on the length of the journey, the value of the animals and the ultimate purpose for which they are to be transported.

Most stable-fed animals may be permitted to proceed on the way without special preparation, but if the animals are taken from pasture, consideration should be given to the fact that a journey of some duration involves them in a sudden and complete change of diet with

its liability to give rise to digestive disturbances. In range cattle, transported at the close of the grazing season, this factor is not of great importance because at that time the lusciousness of the forage plants has disappeared and a change to the dry-feeding régime en route is not a very marked one.

Whenever possible, it is better to prepare the animals for transportation for a few days prior to loading, during which a more or less gradual change from a pasture diet to a dry one can be made. Experienced shippers of cattle often object to the animals being filled with water shortly before the beginning of the journey. On the other hand, they are of the opinion that an abundant ration of roughage, with little or no concentrates, is of a decided advantage. At least, cattle so managed appear to be less subject to shrinkage in comparison with those otherwise fed.

Valuable animals, especially horses, should be prepared for shipment not only by adequate feeding, but also with regard to the prevention of injuries. It is best to have the legs bandaged with soft flannel in such a way that projecting parts, like the carpus and tarsus, are protected against direct injury. Blankets may also tend to prevent harm. A padding incorporated in the blanket where it covers the external processes of the ilium will adequately protect these parts; the use of a hood will often ward off injury to the head.

Pens, chutes and platforms used when loading must be strong enough to withstand both the weight of the animals and the pressure they exert while being crowded. All projecting parts or points must be carefully removed from structures used for the handling of livestock. The floors of chutes and platforms should be roughened or cleated so as to afford a good footing, and inclines should never be too steep.

In loading, most animals can be driven, and the more quietly this is done the better. Undue excitement is apt to produce crowding and confusion which may give rise to injury of the animals.

In railway cars, large animals are placed transversely to the long diameter of the car, and if no individual stalls are used, the animals should be crowded rather closely so as to prevent the undesirable effect of sudden starts and stops. Small animals are crowded promiscuously in the car, but on account of their lighter weight they are less exposed to injury.

The best type of car is the so-called palace horse car. This car is partitioned into adjustable stalls. After the first horse is placed transversely in one end of the car, the partition is swung against it

and securely fastened so as to form a solid side of the stall. The succeeding animals are similarly placed and secured until the car is filled. A feeding and watering alley extends in front of the animals, and each stall is provided with manger and watering trough.

A more commonly used car is one with open, barred sides, with hay racks and iron water troughs, which can be swung to the side of the car in an inverted position for cleaning purposes.

The ordinary plain box car is also used for the transportation of livestock, but in hot weather, the close construction renders this type of car rather undesirable.

Swine and sheep are commonly transported in cars known as "double deckers." They are merely ordinary stock cars with a second floor extending over the lower one at a height of about 3½ feet.

The average inside length of stock cars is about 34 feet, and such a car will hold from 18 to 22 horses, 18 to 20 adult cattle, 70 to 90 swine in a "single decker" and from 100 to 150 in a "double decker"; the latter type of car will take 200 or even more sheep in accordance with their size.

Live poultry is shipped in cars provided with metal crates, each holding about 30 birds. These cages or crates are arranged in superimposed tiers on each side of a central alley for the use of the caretaker who attends to the feeding of the fowls in transit. Such a car will hold approximately 4500 birds. During cold weather the fowls are protected by canvas curtains adjusted to the outside of the car.

All cars regularly used in the transportation of livestock should be cleaned and disinfected between each shipment, and an abundance of straw, sand or other bedding material should be placed on the floor to prevent slipping.

Large animals should be placed sufficiently close to prevent them from lying down. In the handling of trains containing livestock consignments, sudden starts and stops involving severe jolting should be avoided.

For the transportation of individual animals, crates may be used. Such crates must neither be too small nor too large and permit just room enough for the animal to stand in comfort. The width of the crate should not be more than 3 inches in excess of the greatest width of the body. Crates used for horses should be padded at places where projecting parts of the body, as the angular processes of the ilium, are liable to come in contact with the side of the crate. Overhead cross pieces should be so placed that the animal cannot injure its poll by violent contact.

During an extended journey, feed and water must be provided at regular intervals, hay constituting the bulk of the feed. This may be done in transit or by unloading the animals from time to time in specially provided yards.

The latter practice has the advantage of permitting the animals certain periods of rest while feeding. Opinions differ as to how long a journey should continue without such interruptions. This should be largely governed by the total length of the journey, and if animals are being moved for great distances in ordinary stock cars it seems advantageous to unload them for a few hours once in every 24 hours.

Fat swine in transit during the hotter season should be periodically wetted, and most railroads provide for this purpose the necessary equipment at different points along their lines. For the protection of heavy hogs against the effect of hot weather, the practice of suspending bags of ice from the roof of the car may also be advantageous.

Aside from the delays caused by the periodic unloading of animals in transit, a further disadvantage is associated with the fact that feeding yards receiving animals from a wide area, sooner or later become foci of infections for a considerable assortment of diseases.

Whenever possible, an attendant should accompany each consignment of livestock in transit in order to assure to it the necessary care and attention to its needs.

In the transportation of animals by sea the same general precautions as to fitness and preparation recommended for land journeys must be taken. Owing to the fact that such journeys are frequently of longer duration, the animals must be even more critically challenged for the presence of specific infections. This is especially important in the case of horses, as their communicable diseases are apt to spread with great rapidity aboard ship and always tend to run a more malignant course.

Prior to loading, the animals should have become accustomed to the ration given aboard, and it is essential that animals which sustained a long journey by rail should be adequately rested before embarkation. During this period of preparation, horses should have their shoes removed and their feet properly trimmed. Not only will this measure prevent injury from kicking, but it will also afford them a better foothold during excessive movements of the vessel while at sea. Animals having a heavy coat of hair should be clipped, if the weather be hot or the journey made to the tropics; and if lice or other skin parasites are present, these should be exterminated with care.

The animals are loaded and conveyed to the decks they are to

occupy either by the use of bridges and chutes or by means of hammocks or slings operated by the winches used for the handling of merchandise. In hoisting the animals aboard ship, the tackle must always be perpendicular above them in order to prevent them from swinging against the side of the vessel or other structures.

In the selection of vessels for livestock transportation, steadiness at sea and speed are the most important considerations. Ships of large tonnage, wide beam and provided with bilge keels are always to be given preference as animal transports. Such vessels should be either well ballasted or carry other cargo on their lower decks in order to prevent them from being too high out of the water. Steamers capable of making 15 knots per hour are very desirable for livestock shipments.

For cattle and horses, single stalls are the preferable arrangement aboard ship, although most animals may be carried in pens holding from 3 to 4 animals.

American export regulations prescribe that cattle aboard ships must have a vertical space of 6 feet on all decks. They must be allowed a space 2 feet 8 inches in width by 8 feet in length. The same regulations permit 4 animals in one pen and provide that in the end pens 5 head of cattle may be placed. Cattle of less than 1000 pounds in weight may be allowed a width of 2 feet 3 inches; animals in single stalls are given a space 3 feet wide.

Horses must have not less than 6 feet 3 inches, clear vertical space, measuring from the beam of the deck above to the deck under foot. Each horse must be given a space 2 feet 6 inches in width and 8 feet in length, but for very large animals, additional space should be made available. Horses must be kept in separate stalls.

The space allotted to sheep is 4 feet by 14 inches for every full-grown animal and 4 feet by 12 or 13 inches for all animals under 100 pounds of weight.

Sheep pens are not to exceed 20 by 8 feet when tiers are carried, and each tier must have a clear, vertical space of 3 feet.

All stalls must be arranged at right angles to the length of the ship, the animals standing thus at right angles to the direction of travel. In this position, they are best prepared to meet the rolling of the vessel. The stalls are placed along the sides of the ship as well as in the center, the number of rows depending upon the width of beam. With four stalls to the beam there is a row on either side and two rows in the center, the animal's heads facing toward an aisle running between each side and middle row.

The stalls are made of four posts, firmly secured above and below. In those posts are fitted a breast and haunch bar and the separation side bars. All these structures must be of substantial construction. This is highly essential, for during rough weather the posts, stanchions and fastenings may have to withstand a considerable amount of strain. The woodwork must be smooth, the edges are to be rounded and no projecting objects can be permitted.

Cleats should be nailed so as to form a checker-board arrangement with squares of about 10 inches in order to provide a substantial footing. A heavy timber, 4 by 6 inches in cross-section is fastened in front and behind the stalls on the deck, and a lighter timber is also secured to the deck partitions, the floors of the stalls. This arrangement prevents the animals from slipping out of the stalls when the sea is very rough, and at the same time, it contributes materially to the rigidity of the stanchions or posts of the stalls.

Authorities differ on the most suitable length of the stalls. One view is that the stalls should be rather short in order to permit the horses to support themselves against the haunch and breast bars; others believe that it is best to allow the animals more space in order to enable them to maintain a more normal position during the rolling of the ship.

The breast and haunch bars must be adjusted to the proper height for each horse separately, in order to prevent chafing; the breast bar must be adjusted also because the manger is fastened to it.

The decks of the vessel carrying livestock should have drain pipes of adequate caliber; on ships on which the drainage arrangement are so deficient as to keep the decks awash with liquid excreta and flush water, it may be advisable to provide, on all sides above the water line, openings with a flap valve by which the liquid can be discharged over the vessel's side.

The gangways between the rows should never be less than 3 feet in width. This is essential in the maintenance of cleanliness; also a suitable gangway which will permit horses to be exercised.

A sufficient amount of bedding should be used to prevent slipperiness and to absorb at least some of the moisture. A short material such as sawdust best answers the purpose.

Exercise of horses in transit may have some advantages, but it is not always nécessary. If practiced, the gangways should be so arranged that the animals may be led around the entire deck. In order to afford solid footing, the deck may be covered with fiber mats.

The hygiene of animals during transmarine transportation pre-

sents one problem which stands out pre-eminently above all others: the problem of ventilation. On many vessels this remains unsolved.

The exchange of air between decks may be brought about in various ways. A rather primitive method is the one in which the so-called air-scoops, protruding through the port-holes, deflect the air inward. Their action is usually confined to times when a strong wind is blowing or when the ship is running at considerable speed in a direction opposite to that of the wind. In many cases they are wholly inadequate, and furthermore they are not available for the lower decks.

The ordinary ship cowl ventilators are also used. They are used in pairs, one being directed against the current of the air so as to become an inlet and the other being directed away from the air current so as to serve as an exhaust. As a rule, such arrangements are of very limited value, their operations being entirely dependent on the direction and velocity of the wind and on the speed of the vessel.

In the better-equipped vessels used for the transportation of animals, mechanical ventilation by means of fans and blowers may be found. This constitutes the best means of bringing about an adequate exchange of air. It is not dependent on natural forces and is subject to regulation in accordance with the need of the animals in transit.

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CHAPTER XI

DISPOSAL OF WASTES

WHEREVER a fixed abode is occupied by man or by animals, there is bound to be produced a quantity of refuse or waste matter of which a considerable number of substances may form a part. Some of these constitute absolute wastes that cannot be made to serve any ulterior purpose, whereas others are only relatively so and may, in some form or other, be rendered useful.

The presence or accumulation of waste matter is always esthetically offensive to civilized man, and certain types of refuse may be apt to render an environment unsafe from a hygienic point of view. The safe disposal of such materials constitutes a foremost factor in the preservation of the public health and plays an equally important part in livestock sanitation.

The wastes and refuse matter with which the livestock sanitarian is most concerned include the ejecta of the animal body, carcasses, or parts thereof, and the offal of abattoirs or other industrial establishments utilizing raw materials of animal origin.

In the transmission of the microbic and parasitic diseases, the substances mentioned commonly serve as a vehicle for the etiologic factors. Such diseases are frequently designated as filth-borne and their prevention consists, to a large extent, in the application of methods of handling and final disposal of animal waste matter, by which either the causative agents of disease are destroyed or their transfer to susceptible animals is rendered impossible.

The importance of the adequate disposal of body wastes as a means of preserving the public health and of protecting man against some of his scourges has been recognized from early times on. Some of the very first attempts in disease prevention were made in that direction, and may be regarded as the beginning of public hygiene.

In the preservation of animal health this detail of sanitary practice does not always receive the recognition which its importance merits, and even in this day it is commonly neglected. Animals may frequently be found in frightfully foul environments, and if their

feeding habits are such as to cause them to seek their food among the body wastes, the morbidity rate may become adversely influenced in a most conspicuous manner.

The toll inflicted by the filth-borne diseases is frequently no more than the penalty imposed by nature for the violation of one of its laws which ordains that no animal species can live in close or enduring contact with its own excreta without incurring an extraordinary hazard of disease. In some notable instances the contact with the ejecta of other species also may result in the transmission of microbic or parasitic diseases.

The sanitary disposal of the animal wastes mentioned certainly

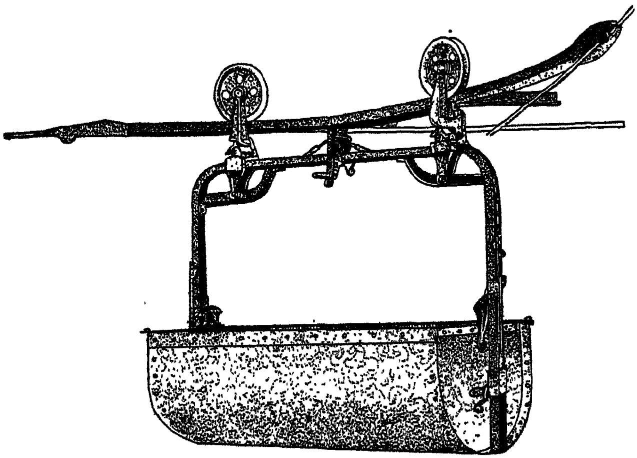

FIG. 51.—Overhead litter carrier. (After Hunt-Helm-Ferris Co.)

constitutes a definite function in livestock sanitation, and although, from the very nature of the problem, the veterinary sanitarian cannot hope to have at his disposal the magnificent equipment employed in municipal hygiene, he is, nevertheless, obliged to bend his efforts toward the elimination of body ejecta and other wastes as most potent factors in the propagation of many diseases.

Stable Manure.—Stable manure consists of a mixture of the various ejecta of the body and part of the bedding used in the stable. Its quantity per animal is subject to considerable variations in accordance with the diet, size and species of animals and the amount of litter which is being used.

For horses the daily amount to be removed will average from 40 to 50 lb., for cattle 70 to 90 lb., for sheep from 4 to 6 lb., for swine

from 8 to 10 lb., per animal, and 100 fowls will yield per day about from 7 to 10 lb.

For sanitary, as well as for economic reasons, the periodic removal of this material is highly essential. It is accomplished in various ways. In small establishments the manure is removed from the stable by means of a wheelbarrow, or when long straw is used for bedding it may be dragged outside with a manure hook.

In larger stables, or wherever labor has to be husbanded, the overhead litter carrier (Fig. 51) is the most practical and convenient means of transportation. By means of the carrier operated on an

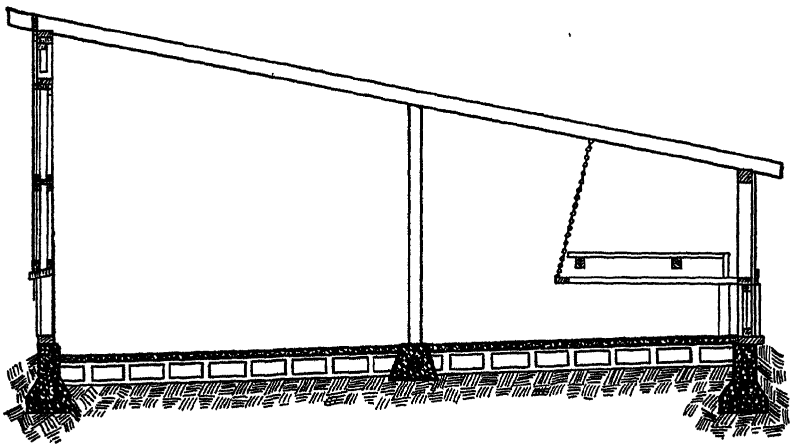

FIG. 52.—Section of poultry house showing position of perches and dropping boards.

overhead rail, the manure can either be directly deposited on the manure spreader or be dumped in a pit for storage.

The feces deposited on the dropping boards in poultry houses is removed by means of scrapers (mortar hoe) and disposed of in the same manner as stable manure.

The urine voided in the stable is either conveyed to a storage tank for liquid manure or is permitted to become absorbed by the litter. In this country at least, the latter method is to be preferred as the most economical and efficient. Especially in cow stables, the bedding may be chosen for its absorbent qualities with this purpose in mind. These qualities vary widely, as is shown by the following table submitted by Winter:

Kind of material	Water retained by 100 lb. of material after 24 hours, lbs.
Wheat straw	220
Oat straw	285
Pea straw	280
Partially decomposed oak leaves	162
Dead leaves	200
Peat	600
Needles of coniferous trees	175
Sawdust	435
Spent tan	450
Air-dried humus soils	50
Mosses and forest leaves	275
Sand	25

Liquid wastes to be stored for future use as manure are conveyed out of the stable by means of open or underground drains. In practice the former will prove to be preferable to the latter, which are very apt to become clogged unless frequently flushed.

The disposal of the manure is either final or temporary by storage. When final disposal is practiced, the material is removed directly from the stable to the land, to be plowed under when convenient. This method is especially approved by agronomists, who state that when manure is spread in a thin layer on the surface of the ground it dries out quickly and the loss of plant food from fermentation is reduced to a minimum.

There is no sanitary objection to such a method of final disposal if the manure is spread on fields not used for livestock and if there is no special infection to be feared. In the case of the latter (abortion, anthrax, blackleg, foot and mouth disease, tuberculosis, helminthoses) or when no land is available for the purpose (in case of summer stabling), storage or intermediate disposal will become advisable.

It was shown by Pfeiler that the etiologic factors of fowl-cholera, swine erysipelas, hog-cholera, and tuberculosis were destroyed with certainty in two weeks by the mere action of heat developed during the fermentive process within the stored manure. To bring this about, the manure is stored in piles not less than a cubic meter in volume, and there must be a thorough mixing of the excreta and the litter in a proportion of 2 to 3. A certain amount of moisture must be present in order to bring about the biologic action resulting in a temperature which should not be less than 60° C.

This temperature, *per se,* was not sufficient to destroy the virus of anthrax, but it was shown that, combined with the substances

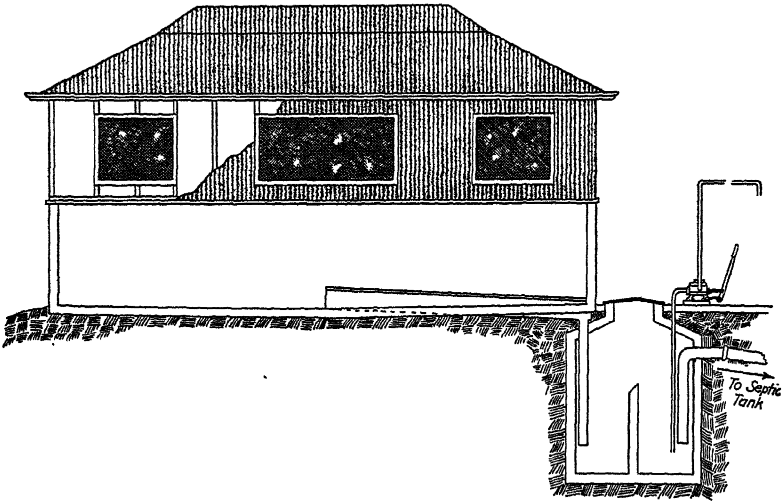

FIG. 53.—Covered manure pit with cesspool.

present or formed in the course of the fermentation, it brought about the destruction of the germs as well as that of their spores.

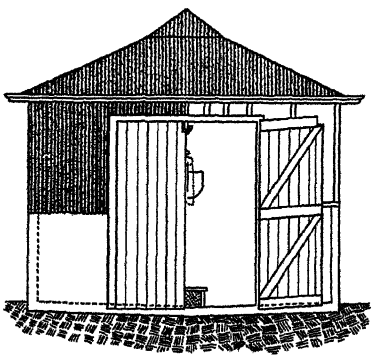

FIG. 54.—Covered manure pit, front elevation.

When for sanitary or agronomic reasons manure is to be stored, this should by preference be done in covered, well-constructed, manure pits. Such pits are best made of impervious material and are to be surrounded by a wall about 5 feet high, provided with an opening wide enough for the passage of a vehicle. A roof is essential from an agronomic point of view, as its shelter prevents the leaching of valuable ingredients.

The liquid or semi-liquid stable wastes may also be conveyed to such a pit if the topography of the farmstead permits. This would contribute an amount of moisture essential to the biologic processes by which the manure is freed of microbic or parasitic factors of dis-

ease. There should be a means of exit in the event that more liquid were admitted than the mass could absorb. Such an excess of liquid could then be conveyed to the cesspool provided for storage or disposed of by means of the septic tank receiving the house sewage.

An attempt should be made to render the covered manure pit fly-proof, as stable manure is the normal breeding medium for flies. For this, as well as for esthetic reasons, manure pits or piles should be as far removed from the house, stable or dairy buildings as is consistent with good management. The abatement of the fly pest is an advantage particularly associated with the method of disposal which delivers the manure upon the land immediately after its removal from the stable.

When the liquid stable wastes are permitted to drain into underground vaults or tanks, the contents of the latter are removed periodically by pumps, or otherwise, into tank wagons and by them scattered over the land by means of a sprinkling device. The collecting vaults should have a capacity of from 12 to 15 cubic feet per cow.

Body Wastes in Outside Enclosures.—Even more than in the floored stable, where the periodic removal of the body wastes can be readily accomplished, is there reason to look upon the presence of fecal matter in yards and pens with a certain degree of apprehension.

In such enclosures the number of animals is often quite out of proportion to the area occupied, and hence there comes about an accumulation of organic material, body wastes, etc., far in excess of the capacity of the soil to dispose of them by the process of biologic purification. Nor is it ordinarily possible to remove such materials in a manner which can fulfill sanitary requirements.

If, in addition to the gathering of a considerable amount of body wastes, the natural feeding habits of such livestock as poultry and swine impels the animals to search for food in the soil, the hazards associated with infection and parasitic invasion are apt to assume proportions not observed in any other environment.

The continuously occupied hog or poultry yard must thus be recognized as a menace to the health of its occupants. In this type of environment the animals are commonly compelled to remain during the full length of their existence, and there they are provided with food and water under conditions which are particularly prone to gross contaminations. On a relatively small area of ground, large amounts of fecal matter are continually deposited, and lack of drainage often causes heavily polluted accumulations of surface water to remain available to the animals for long periods.

Under such circumstances, a truly vicious circle soon is established after the introduction of the microbic or parasitic factors of disease. The soil becomes glutted with organic materials and pathogenic elements in amounts far in excess of its digestive powers, while animals either actually diseased or merely the carriers of virus belonging to one generation uninterruptedly are contributing their quota of virulent materials to do damage to the one following.

The problem presented by the filth-borne diseases of poultry and hog yards is not unlike the one associated with disorders of man having a similar etiology. Present-day urban existence would be seriously menaced without the special efforts of sanitation concerned with the safe disposal of fecal matter, and to a marked degree is this true of the animal populations of small plots of ground set aside for their confinement.

For obvious reasons, the more refined devices in use for the sanitation of cities cannot find application in the safeguarding of flocks and herds kept on limited areas of land. The solution of the problem may, nevertheless, be approached in a more or less satisfactory manner.

Interrupted Usage.—Interruptions in the use of yards allows a measure of time during which the soil, by the process of biologic purification, can complete the reduction of its organic impurities and during which various pathogenic elements are disposed of by adverse living conditions, by subsidence or through the agency of predatory micro-organisms.

To bring this about, provision should be made for space sufficient for three separate yards: one to be used for a season and the other two to remain uninhabited by livestock and to be devoted to cropping or garden purposes. Each year a fresh lot is put to use, so that two years elapse between successive occupancies.

The desirable effects of such a method of rotation are further enhanced by adequate drainage. In this connection, subsoil drainage offers a special advantage because it facilitates a perpendicular flow of precipitation water and hence also the subsidence of the biologic factors of disease.

The yards not occupied should be used for cropping, preferably that which requires a maximum amount of cultivation in order to promote the biologic processes of the "living earth" and to facilitate the subsidence of spores, parasite eggs, etc., which are the least subject to the purifying action by the microbic elements peculiar to the soil.

Hard Surfacing.—If yards and other enclosures are paved with concrete, the method of disposal of fecal matter and other wastes is not different from those employed in stables. The material to be removed is gathered by means of scrapers (Fig. 55) and either deposited in bins for temporary storage or directly distributed over the fields from vehicles or by means of manure spreaders. Only in regions where a rigorous winter climate causes the wastes to become solidly frozen fast to the surface is it difficult to maintain a sufficient degree of cleanliness. Hard-surfaced lots should be provided with adequate means of drainage, the storm water contributing to their sanitary condition.

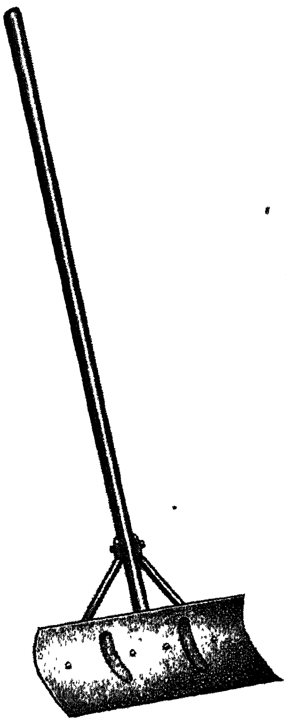

FIG. 55.—Manure scraper.

Graveled Lots.—In enclosures set aside for poultry a thick covering of gravel makes it possible to do away with the most objectionable features of fecal contamination in a more or less efficient manner.

The space to be covered should be prepared by sloping the surface in a given direction, preferably in such a manner that the lowest part coincides with the middle of the lot. At that point a line of drainage tile is placed on the surface and is prolonged out of the enclosure to a point where drainage water can be safely disposed of.

A row of concrete blocks or planks is placed along the fence and the space within filled with gravel. A hard, round gravel is preferred for the purpose. It should be freed of the smaller particles by sifting through a screen of half-inch mesh. A layer approximately 1 foot in thickness is sufficient for the purpose. Aided by precipitation water or by flushing by means of a hose, the fecal matter finds its way to the soil below, where it disintegrates and is conveyed away by the drain.

Human Excreta and Wastes.—Although the microbic diseases peculiar to man do not constitute a serious menace to the health of animals to be constantly reckoned with, the adequate disposal of household wastes and of human excreta must, nevertheless, be given

a definite place in the sanitation of establishments where man and animals live in close contact.

Garbage has been shown to serve as a vehicle of human tuberculosis when fed to swine, and this form of waste matter may also become instrumental in conveying the same disease to poultry and other livestock, if it should contain the viscera of affected fowls which were drawn for table use.

The dissemination of hog-cholera by means of meat trimmings contained in kitchen and table refuse must be regarded as a possibility to be reckoned with. Bits of trichinous pork available to rats

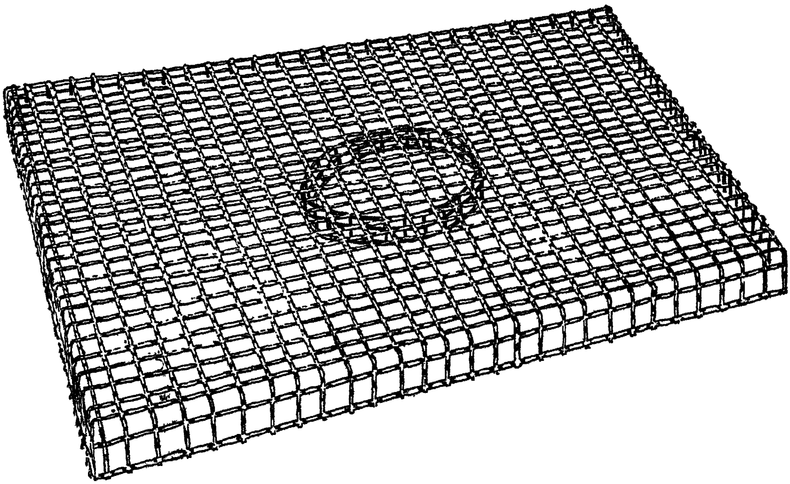

Fig. 56.—Hardware cloth panel, used in poultry houses to prevent fecal contamination.

or other animals may, in time, tend to propagate the parasites if consumed by swine.

Human feces carelessly disposed of are practically the only means by which cattle and swine can become the hosts of the cysticerci of *Taenia saginata* and *Taenia solium*.

Aside from the animal diseases which may be transmitted through the agency of human refuse and excreta, the proper disposal of these materials is warranted as a means of promoting the sanitary safety of dairies and other establishments where food of animal origin is being handled or prepared. Milk-borne epidemics of typhoid fever frequently have their origin in dairies where the disposal of sewage is faulty or where it is neglected altogether.

Garbage.—Although the disposal of garbage has, ordinarily, but a more or less remote connection with livestock sanitation, the fact that it may contain certain etiologic factors of microbic or parasitic diseases present in offal of animal origin is a sufficient reason for this detail to receive attention. In addition there is the possibility of poisonous substances being present in garbage.

The destruction of this type of waste by burning is the most efficient and desirable method for its disposal. In small amounts, this can readily be done in ordinary stoves or heating furnaces. If larger quantities are to be destroyed, a small incinerator of simple construction may serve for the purpose.

When the use of fire is not readily applicable, the garbage of rural habitations can be safely disposed of by burying, at least so far as it is liable to decomposition.

A convenient method of dealing with small amounts of household wastes is the following: By means of a common post-hole auger, a pit is made in the ground. This hole should not be less than 6 feet in depth and deeper if possible. The upper part of the pit is protected by means of a barrel from which bottom and top have been removed. The upper part of the barrel is made to project above the level of the ground and provided with a movable cover.

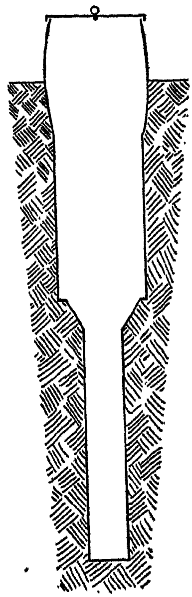

FIG. 57.—Pit for garbage disposal.

The garbage is deposited in the pit, and in order to promote its decomposition some water or kitchen slop should be added. The material so treated decomposes with some rapidity, and the amount of garbage which may be digested in this manner in one pit is quite considerable. One pit may serve an average household during the warmer part of the year, but when a larger need is to be supplied, two or more must be made, and used alternately. When a pit is filled to within a foot or two of the surface the barrel is removed, the hole filled with earth and a new pit made ready for use.

In certain soils of loose texture this method is, of course, not applicable. In such cases the garbage may be incorporated in the contents of the common manure pit and there subjected to decomposition.

Municipal garbage is occasionally disposed of by feeding it to swine, the disadvantage from a sanitary point of view being appar-

ently outweighed by economic considerations based upon the nutrient value of the material. It is, however, doubtful that this practice can be regarded as "disposal" inasmuch as garbage is apt to contain a considerable amount of inedible material, which must either be plowed under or hauled away for destruction by some other method. Garbage feeding is more of a venture in animal husbandry than in sanitary practice.

Aside from a certain risk of disease transmission, there is no valid objection to the practice so far as the value of the pork thus produced is concerned. The animals should be protected against hog-cholera by immunization, and their exposure to tuberculosis infection in the garbage feed yard is probably not greater than on many farms. There remains the risk of trichinosis; at present there are no data from which this danger can be correctly estimated.

Occasional deaths from poisoning by salt, minerals and decaying organic materials must be reckoned with, and adverse unsanitary conditions may likewise contribute to the losses.

The most valid objection to the feeding of garbage to swine is an esthetic one, as the establishments used for the purpose are commonly extremely filthy and malodorous.

Human Excreta.—The safe disposal of human excreta is to this day one of the most efficient among the general means for the protection of the public health. As already pointed out, it likewise contributes to the prevention of certain parasitic diseases of animals, and on dairy farms it is imperative for the protection of the consumer of raw milk.

In organized communities the disposal of sewage is a matter of public effort, but in the open country, where the problem may also confront the livestock sanitarian, its solution is dependent on individual initiative and hence it is frequently faulty or neglected altogether.

In the disposal of fecal matter in isolated habitations, various types of equipment are in use, and some of them are adequate and safe. In order to be so the following conditions must be fulfilled: first, all possible contact between body wastes and food or water must be prevented; second, access of flies and other scavenger forms of animal life must be rendered impossible; third, human excreta should not be deposited on truck gardens or discharged into streams or other bodies of water before they have undergone decomposition to the extent that all microbic or parasitic causes of disease have been destroyed; fourth, esthetically offensive features should be eliminated;

fifth, simplicity of construction and functioning with a minimum of attention are imperative.

Privies.—The equipment in use for the disposal of human excreta in rural habitations varies considerably, ranging between the filthy, unsanitary open privy hole and the perfectly maintained flushing system.

The so-called pit privy, if properly placed and constructed, is a relatively safe means of disposal. It has the advantage of cheapness and simplicity, and if habitually used it does away with the dangerous promiscuous distribution of excreta on the surface of the ground.

The privy house is placed over a pit, curbed or not, in accordance with the nature of the soil and banked to render the pit by-tight and to prevent the inflow of surface water. When about two-thirds full the house should be moved over a new pit.

In the pail privy the fecal matter is collected in a movable receptacle which is periodically emptied. This type of privy can be used as a dry earth privy when the user covers each evacuation with a small quantity of dry earth. This renders the privy inodorous, but does not destroy the pathogenic elements which may be present in the contents. A convenient type of pail privy may be so constructed that the excreta are collected in a tight box mounted on skids (Fig. 58). This facilitates its removal and final disposal.

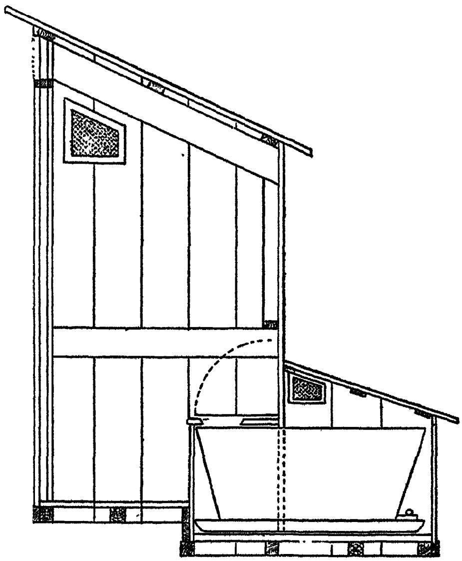

FIG. 58.—Rural privy with removable receptacle.

The vault privy consists of a pit curbed with such impervious material as concrete, stone or wood over which the privy house is built. The vault is extended beyond the rear of the house in order to permit ready access for emptying. The vault may be divided in two compartments of which one is in use at a time. When one of these is filled, it is closed and the contents are left undisturbed until

the other one is also full, when the first one is emptied and put to use again.

The chemical closet is based on the principle of destroying and sterilizing the excreta by chemical action. Caustic soda and various disinfectants are added to the contents of the receptacle.

In the septic or L. R. S. (Lumsden-Roberts-Stiles) closet the principle of the septic tank is applied to the vault type of privy. The vault is provided with an effluent through which the overflow is conveyed away. In its operation, water is added, from time to time, to the contents in order to promote decomposition. This type of equipment requires more attention than the ones previously mentioned, and when this is lacking its sanitary value is greatly impaired. The overflow from this sort of equipment is not certain to have been sufficiently freed from infective agents, and hence it requires further treatment. In regions having severe winters, this means of disposal may be of questionable value unless well protected against freezing.

Septic Tank.—The septic tank is a necessary adjunct of the water carriage system of sewage disposal in rural habitations, its introduction being a marked step forward in rural hygiene. It is designed to receive all liquid wastes in addition to house sewage, and this alone commends it also to the livestock sanitarian.

A septic tank consists of one or more underground, water-tight chambers (Fig. 59), through which the sewage slowly passes. During this passage, the organic materials are subjected to bacterial action or putrefaction by which their ultimate and complete disintegration can be more readily brought about. It serves, thus, as a depository in which a substantial portion of the solid excreta is liquefied and from which it can be more readily conveyed for final disposal.

The tank, however, is not to be regarded as a destructor of the pathogenic factors which may enter into it, although there can be no doubt that the microbic causes of disease meet with conditions very unfavorable to their existence in the fermenting and putrefying contents. The final destruction of the more resistant elements is more apt to follow when the decomposition initiated in the tank by the anaerobic bacteria is continued and completed by the action of aerobes in which oxidation is a prominent feature. Hence there is need of a terminal treatment of the material discharged from the tank in which contact with the upper soil layer is of the utmost importance.

Much of the material deposited in the septic tank, although subjected to a degree of putrefaction, does not become reduced to the

extent of being carried out with the water and settles to the bottom of the receiving chamber. This deposit or sludge requires to be periodically removed. The solid matter entering the septic tank is on the average reduced in weight by only about one-third, so that the earlier expectations of the tank not requiring attention proved to be an illusion.

Biolytic Tank.—With a view of bringing about a more complete reduction of the sludge, the biolytic tank was designed. This is merely a modification of the septic tank, differing from the latter in its operations by a more or less continuous agitation of the contents so that the products of decomposition are more readily removed. The

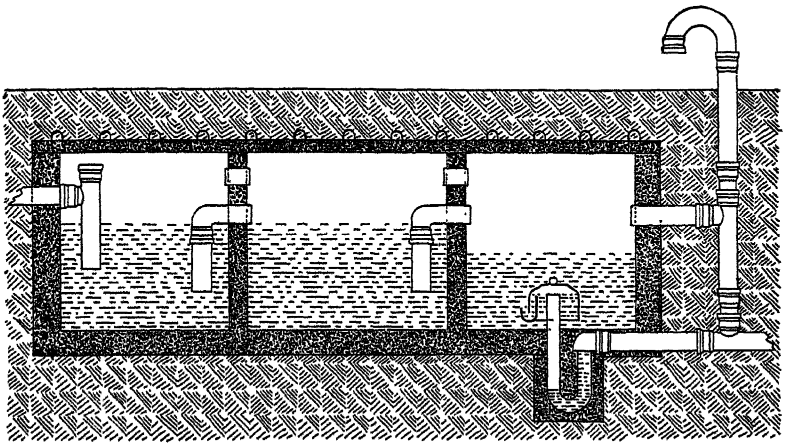

FIG. 59.—A three-chamber septic tank.

agitation is usually brought about by the flow of the sewage which enters the tank. Under experimental conditions the results were satisfactory, but they have thus far not been sufficiently studied in actual practice to warrant an estimate of the worth of this type of equipment.

Imhoff Tank.—Another variation of the septic tank principle is found in the Imhoff tank, which is so constructed that the substances which ordinarily enter into the formation of sludge are subjected to septic action without being in prolonged contact with the sewage. This is accomplished by providing two compartments, placed one above the other, the upper one constituting the settling chamber and the lower one the digestion chamber. The two compartments are connected by a narrow slot at the bottom of the settling chamber.

During the operation of the equipment the sewage passes slowly through the settling chamber. Some of the solids rise to the surface, while the heavier materials settle and pass through the slot into the digestion chamber, where they decompose, forming a sludge which can be readily removed. The Imhoff tank furnishes a more efficient means of sewage disposal than the simpler septic tank, but requires more care and attention than the latter.

Final Disposal.—The various types of equipment in use for the disposal of excreta serve the primary purpose of safe storage combined with a more or less active process of decomposition. In none is the disposal a final one, which, after all, constitutes the principal problem, particularly in isolated rural habitations where a trained personnel is not constantly in attendance. As the quantity of material to be handled periodically is relatively small, its safe, final disposal offers no unsurmountable difficulties.

In the case of the pit privy, the removal of the privy house and the filling of the pit with earth is all that is necessary. If the pit is so situated as to safeguard wells against seepage, this form of final disposal, even if somewhat primitive, is indeed safe enough.

With the pail privy, the vault privy and some types of the chemical privy, the contents of the receptacles must be removed and transported; this should be done with care in order to prevent the pollution of the soil and its watershed with fecal matter which may yet contain pathogenic elements in a viable state.

For the final disposal of the fecal matter removed, its burial is probably the best and most practicable procedure to be applied. A pit is dug in some safe and out-of-the-way place into which the containers are emptied, after which the pit is filled with earth. Or the material may be added to the contents of a stable manure pit or vault and there left undisturbed until decomposition has been completed, when the material can be applied as fertilizer to land used for cropping.

A different problem is presented by the liquid discharges of the septic tank and its modifications, although the periodically removed sludge may be disposed of in the manner indicated above. For the disposal of the liquid material, subsurface irrigation is the method most commonly adopted for the smaller installations.

This method aims to discharge the effluent material into the soil, where the "living earth" completes the decomposition already initiated in the digestion chamber of the tank. It is accomplished by

means of a ramifying sewer into which a given quantity is periodically discharged by means of an automatic syphon.

The intermittent filling of the distribution system not only brings about an even diffusion of the sewage discharged, but it also allows time for the soil to become aerated anew and prevents it from becoming water-logged or overcharged with undigested sewage at certain points.

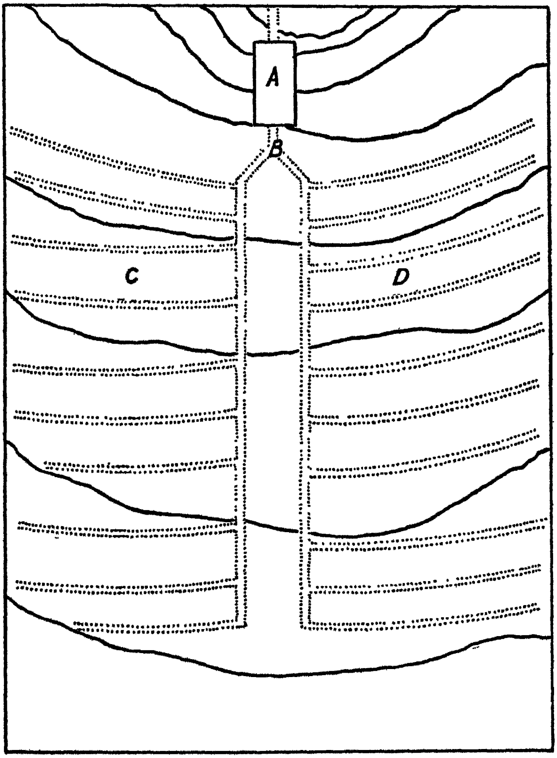

FIG. 60.—Sewage disposal field.

A. Septic tank. *B.* Sewage switch. *C.* Deep tile for winter use. *D.* Shallow tiles for summer use.

The distribution field must be on a lower level than the tank in order to permit the tile to be laid near the surface of the ground where biologic purification is most active. A supplementary and more deeply placed system of distribution tile has been recommended for sections where the ground is apt to freeze to a considerable depth.

The length of the tiling, the size of the distribution area, as well as the arrangement of the main sewer trunk and its secondary branches, are largely determined by the amount of sewage to be disposed of, the nature of the soil and the topography of the land. From 40 to 80 feet of a 3-inch tile per person served will be sufficient for most soils, although some soils may be so impervious as to be unsuitable as an absorption bed. In heavy clay soil the tile should be laid in a trench partially filled with gravel, cinders, crushed stone or some other material furnishing a porous medium.

Disposal of Industrial Wastes.—The liquid wastes discharged from industrial establishments using raw materials of animal origin frequently arrest the attention of livestock sanitarians. Rendering plants, abattoirs and above all, tanneries, may become factors in the dissemination, even in the introduction, of certain diseases by the pollution of water courses into which their wastes are discharged. Especially tanneries using foreign hides have frequently been shown to be instrumental in the establishment of anthrax foci in the manner indicated.

Owing to the resistant character of the anthrax spores, the problem is often a perplexing one. Its solution has been attempted in various ways, no single one of which has always brought the desired results.

The methods used are: First, the disinfection of the raw materials (hides, wool, hair) before they enter in the process of manufacture; second, the protection of the livestock endangered by immunization; third, adequate treatment of the liquid wastes before their discharge into a water course. At this place we are concerned only with the latter, although the routine application of all the methods named will usually be required in order to bring about a maximum degree of safety.

The discharge water of tanneries and similar establishments should be subjected to sedimentation in specially constructed basins; this process is particularly enhanced by the addition of such coagulants as lime, iron sulphate or alum.

In accordance with the volume of discharge to be treated, a number of basins should be available in order to provide ample time for the sedimentation to become completed. While one basin is being filled, the others remain quiescent, and after the sedimentation and clearing are complete, the contents of the latter can be passed over a filter bed as additional measures of safety. The elimination of the coarser particles by screens before the waste is conveyed into the sedimentation basins adds to the efficiency of this method of purification.

The sludge which gradually accumulates in the sedimentation basins and which contains the greater part of the pathogenic factors should receive further treatment. This is best accomplished by the use of disinfectants in sufficient concentration, after the supernatant water has been discharged into the filtration bed. The addition of 2 per cent hypochlorite or equivalent volume of liquid chlorine will assure a maximum degree of safety if the disinfecting action is permitted to continue for a period of three days.

Disposal of Carcasses and Parts.—An adequate disposal of carcasses or parts thereof is always indicated as a matter of common decency, but if the animals concerned were affected with certain communicable diseases it becomes an imperative necessity. A considerable assortment of pathogenic elements contained in carcasses remain viable and virulent for some time and are liable to contaminate an environment. Whereas in a number of diseases the causative organisms succumb shortly after the death of their hosts there are others in which the etiologic factors remain virulent for a considerable length of time, and if they are spore formers (anthrax, blackleg, braxy) their viability is a lasting one.

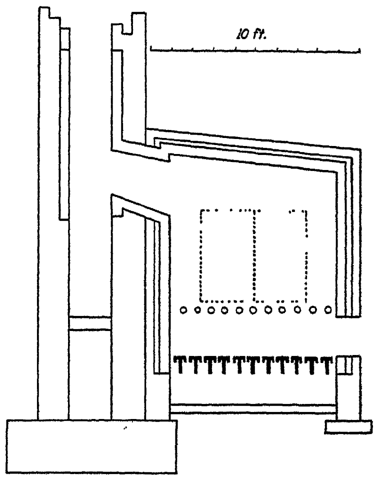

FIG. 61.—Longitudinal section of University of Nebraska incinerator.

The carcless disposal of dead animals or the absolute neglect of dealing with them altogether is commonly responsible for the establishment of more or less permanent foci of infection. The practice, not altogether uncommon, of dragging a carcass to some out-of-the-way place and there leaving it to the mercy of the elements or to be consumed by scavenger animals (dogs, coyotes, hyenas, swine, buzzards) is especially to be condemned. Through the aid of such animals, virulent material may be carried far and wide, and in addition, consideration must be given to the possible transportation of virus by water courses and the wind.

The methods of disposal vary and may be divided in two classes: those in which the total destruction of the carcass is aimed at, and those having the purpose of utilizing the material for industrial ends.

To the latter, preference should always be given if the material can be transported and manipulated in a manner by which infection danger can be excluded. The industrial disposal of carcasses is, however, possible only in limited areas, where a dense livestock population warrants the establishment of the necessary equipment.

In a large part of the world, where a less intensive animal husbandry prevails, the more destructive and economically less desirable methods must be followed. The latter consist of burial and incineration.

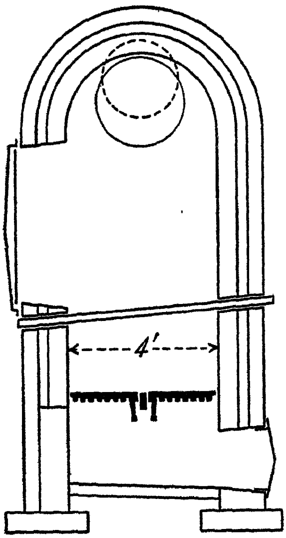

Fig. 62.—Cross section of University of Nebraska incinerator.

Burial.—To bury carcasses is perhaps the most commonly practiced method of their disposal. It is, of course, vastly superior to the old custom of permitting dead animals to decay on the surface, but it is not an absolutely safe method in connection with such diseases as anthrax, and others caused by spore-forming microorganisms. The hazard of the spores eventually reaching the surface cannot readily be disposed of. However, if burial takes place in pits or in trenches sufficiently deep this method of disposal is quite safe, under most circumstances. The uppermost part of the animal buried should be not less than 4 feet beneath the surface; the pit should be adequately filled with earth, over which stones may be placed wherever marauding animals are to be feared.

In communities a certain piece of ground may be set aside for the disposal of carcasses. Such a burying ground must be sufficiently far removed from inhabited places, and the topography of the land and the behavior of the ground water must also be taken into consideration. If there is any choice at all, the character of the soil should likewise be a determining factor in the selection. The type of soil which tends to provide the best opportunity for the most rapid and complete deterioration of the carcass is always most desirable for the purpose. Hence the soil should be porous, light, and so well drained that the water table remains at least 8 feet below the grade line at all times.

In the open country, where, as a rule, established burying grounds are not available, animals are buried as close as possible to the place

where they died, with the necessary regard to the proximity of habitations, sources of water supply and other factors of hygienic importance.

Especially when dealing with the carcasses of animals dead with the more virulent and resistant infections, all transportation not absolutely essential should be avoided, and when disposing of dead animals

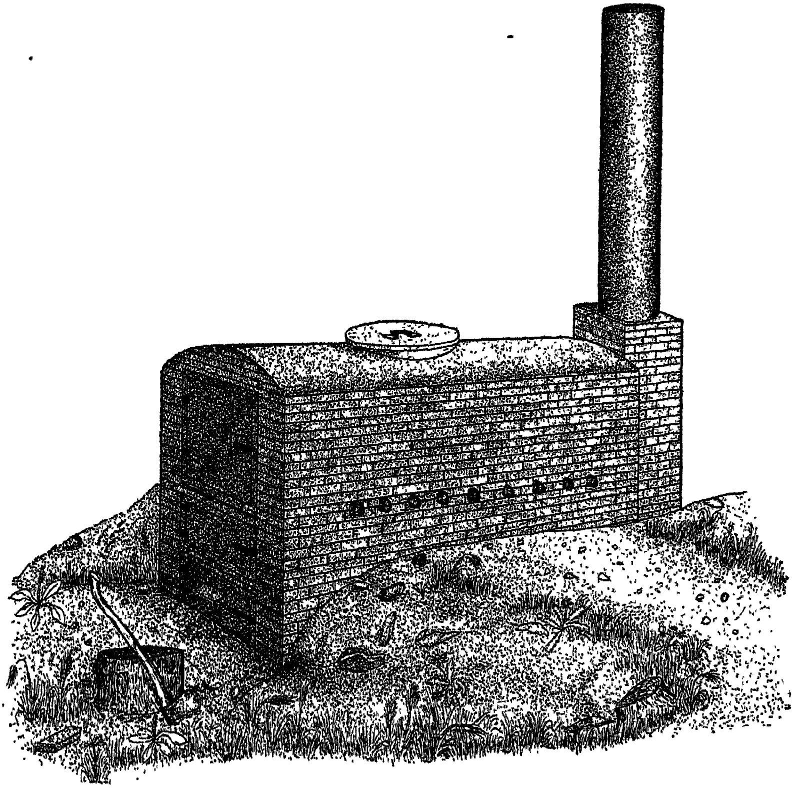

FIG. 63.—A small incinerator for small carcasses, garbage, etc.

in pastures or on the range it is best to dig the pit in the immediate vicinity of the carcass. Such carcasses should be buried intact, without the removal of the hide, and after they are placed in the pit the surface earth soiled by the body discharges or blood must be carefully removed and deposited in the depth of the pit.

The carcasses of small animals such as pigs, aborted calves (including the afterbirth) when found at pasture can be most readily

buried in a deep hole dug by means of a post-hole auger, the polluted earth being also scraped into the pit.

Incineration.—The destruction of carcasses by fire is, without doubt, the most efficient method of disposal wherever hygienic requirements only need to be considered. Incineration is especially indicated wherever a highly resistant virus (anthrax, blackleg) must be dealt with in a final manner.

The *burning of carcasses* is accomplished either by means of an open fire in a previously constructed trench or in permanent incinerators. The former is the method of cremation followed in the field; the latter is more particularly suited to the need of institutions in which virulent materials require to be safely destroyed.

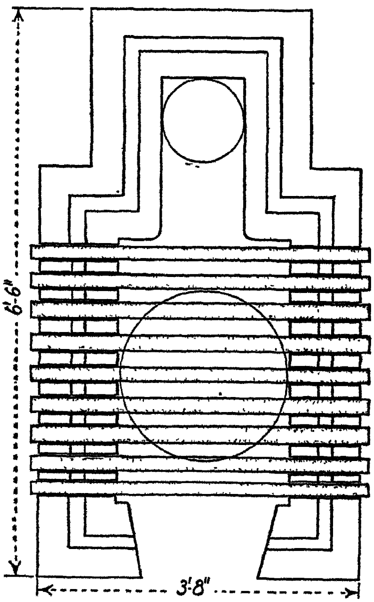

Fig. 64.—Construction detail of small incinerator.

Small carcasses can be readily and completely cremated by means of a primitive pyre, but the incineration of those of the large domestic animals requires a more elaborate preparation in order to meet the requirements of sanitary practice.

For the purpose of field incinerations, use is made of a previously prepared trench into which the fuel is placed with the carcass on top. In practice, certain variations in the use of the incinerating trench have been developed.

In one (Niemann-Profé), the trench is about 8 feet in length and about 6 feet in width, with a depth of approximately 2½ feet for the larger carcasses and of more restricted dimensions for the smaller ones. In the bottom of this trench a smaller one is made running its full length, but of a width of 4 feet and a depth of 2½ feet. The smaller trench placed in the center of the larger one leaves a shoulder of 1 foot on each side, thus providing a support for crosswise-placed bars of iron rails upon which the carcass comes to rest.

Before the latter is placed in the trench the smaller one is filled with fuel, usually wood, mixed with straw, moistened with kerosene

or fuel oil, in order to promote adequate ignition. The carcass is then placed upon its supports, some more fuel piled on the sides and the whole ignited.

A less laborious method depends on two trenches dug crosswise (Smith). Each trench is 7 feet in length, about 15 inches wide and 18 inches deep at the point where the trenches intersect, becoming shallower toward the ends. The earth removed is piled into the angles formed by the trenches, and this supplies the resting place of two pieces of railway iron or of an old automobile chassis for the support of the carcass. The fuel is placed in the intersection of the two trenches.

In another method (Fabritius) a trench not less than 6½ feet in depth and of suitable length and width is prepared; this space is filled with cord wood placed crosswise in alternating layers, but in such a manner that at either end of the trench there remains an open space in order to secure sufficient draft. Those spaces are filled with inflammable material for the purpose of ignition. The carcasses are placed upon the fuel, more fuel is placed on top, and the whole is enclosed in a layer of sods or damp stable manure, in order to secure a slow combustion and to husband the heat generated. The evisceration of the carcass facilitates incineration, but this is permissible only in the absence of material containing a highly resistant virus.

Aside from the type of fuel usually available, use has been made of fuel oil applied as a spray. With a battery of atomizers it would be possible to incinerate a carcass with fuel oil alone, and even one or two would be a valuable addition to the ordinary trench method in which wood constitutes the bulk of the fuel. It is conceivable to construct an ambulatory incinerator for field work, by placing a pressure pump on a truck along with the required number of atomizers and a supply of oil.

For institutions or laboratories having to dispose of an abundance of virulent material which cannot be used for industrial purposes, and where often stable manure also must be incinerated, fixed crematories are often used for the purpose. Although such incinerators vary considerably in the details of construction, a common principle of building and operation may be followed. Such crematories consist of a space walled in by fire-resistant material, such as fire-brick and cast iron. The enclosure is divided in three superimposed compartments. The lower one serves as ash pit, and into this the incombustible residue is collected after incineration has been completed. This compartment

is separated from the fire-box above by means of a common boiler grate. In this compartment the fuel used is burned.

The upper section or incinerating chamber is also separated from the fire-box by a grate, constructed of heavy iron pipes 3 inches in diameter, each pipe being inserted through the side walls of the structure through sleeves consisting of sections of a large-caliber pipe. The whole constitutes the incinerating grate. By this arrangement, burnt or defective pipes can be readily removed and replaced by new ones. The pipes must be placed on an incline so that when heated a certain amount of outside air will pass through them in order to bring about a degree of cooling.

The carcasses to be destroyed are passed into the incinerating chamber through two cast-iron doors movable on a trolley; smoke and

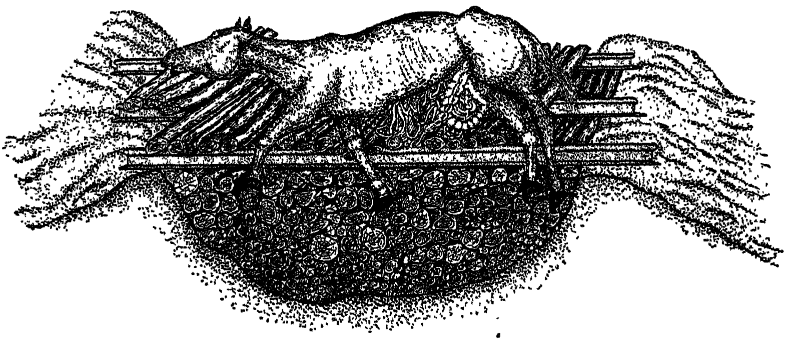

FIG. 65.—Field incineration.

gases are conveyed away through a smoke stack, usually placed at one end of the structure.

In the operation of the incinerator the fire-box is filled with wood, or coal, and a layer of wood is placed upon the pipe grate of the incinerating chamber before the carcasses are introduced.

Industrial Utilization of Carcasses.—When any of the methods outlined above are used, the carcasses cannot be utilized for any purpose and much valuable material is lost. In order to obviate this loss, other methods of disposal are followed by which certain products having a market value can be removed.

The most simple of these methods is the one in which the fat of the carcass is fried out to serve as the raw material for soap factories. In others, the carcasses are treated with sulphuric acid, and the resulting products find their way into commerce in the shape of crude fat and fertilizing materials.

A more generally used method, especially employed to deal with abattoir offal and condemned carcasses, depends upon the digestion of the animal tissues by means of steam under pressure. This method is the most efficient both from an economic and from a sanitary point of view.

Transportation of Carcasses.—The transportation of carcasses to rendering establishments or for final disposal otherwise must be so safeguarded as to preclude the dissemination of virulent materials. When the animals succumbed to the more highly infectious diseases, they must not be dragged over the ground, and some vehicle from which no body discharges can escape and which can be adequately disinfected should be used for the purpose.

Wagons used for the transportation of carcasses to regular establishments must be so constructed that the load is perfectly enclosed, preventing the access of insects and the escape of fluids or other substances emanating from the carcass. They must be provided with the necessary equipment for a ready loading and unloading without these operations being accompanied by the soiling of the workers or the environment with virulent substances.

The interior of the wagon must be metal lined so as to make a thorough cleaning and disinfection possible. Disinfection should be extended to all utensils, persons and premises with which the carcasses come in contact.

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CHAPTER XII

DISINFECTION AND DISINFECTANTS

THE part played by the environment in the propagation of transmissible diseases and as a place of abode for pathogenic agents has from early times either been suspected or clearly recognized. Various means have been devised to render an environment safe for animal occupancy; to do so effectively constitutes a problem of more than passing importance. The efforts having this achievement as their purpose are included in what is commonly termed disinfection.

Disinfection may be defined as the destruction of the microbic causes of disease. As the term is applied in sanitary practice it is to be distinguished from sterilization and antisepsis, which aim at the destruction of all forms of microbic life whatever they may be. Disinfection, on the other hand, signifies action against a definite etiologic factor of specifically determined disease, either present actually or within a more or less recent past. As such, disinfection may bring about the destruction of the virus concerned, but it may be incapable of destroying other microbic agents which may be present.

In livestock sanitation, disinfection is particularly directed against the pathogenic elements either present in the environment or on the external parts of the animals concerned or of those exposed to a given infection. The destruction of microbic pathogens within the body may be likewise aimed at, but such an effort is ordinarily of therapeutic import and is commonly designated as chemotherapy.

Disinfection must be practiced wherever the purifying factors of nature operate too slowly or too imperfectly and wherever there are no permanent obstacles to prevent its effectiveness. With very few exceptions, the disease-producing micro-organisms neither grow nor multiply outside the body of their hosts. However, even removed from the latter, they may retain their vitality and virulence for varying periods, depending on the biologic qualities of the germs and on the character of the influences to which they may be exposed. In some instances their environmental existence is ephemeral, but on the other hand, such organisms as the spore bearing anthrax, blackleg, and

tetanus bacilli may remain fully viable and virulent for years, and the eggs of certain helminths and protozooic forms may be endowed with a similar quality.

What is known of microbic longevity is almost entirely based upon laboratory observations, and it is by no means improbable that the artificial environment of the germs studied only partially represented the conditions which they are apt to meet in the natural state. Empirical evidence tends to show that pathogenic elements may be preserved outside the animal body for considerably longer periods than those indicated by experimental data.

Under natural conditions, most environmental infection is slowly dissipated under the influence of desiccation, age, sunlight, oxidation, dilution, and predatory biologic forms. These factors are considered in the chapter dealing with the parts which compose the environment; they lie outside the scope of disinfection dealt with under the present heading.

Application.—Disinfection is indicated wherever a disease more or less transmissible by direct contact is known to exist. It must be done without delay as soon as possible after this fact has been established. We speak of concurrent and terminal disinfection. The former finds application during the course of the disease and involves the destruction of the microbes in the immediate surroundings of the affected animals, such as the stable and its appointments, the secretions and body wastes, and all other objects which were exposed to contamination. The latter pertains to the same objects, but is applied after the death or removal of the animals concerned. In either case, the objective is to hinder the environment from playing a further part in the dissemination of the virus.

The success of disinfection is always dependent on the thoroughness of its application. Partial disinfection is no better than none at all and often worse. Hence it is a sound practice to carry on the disinfection process in excess of apparent actual requirements or of the indications presented by a given case.

Limitations.—Even if a disinfection process is carried on with great thoroughness, it is not always possible to be entirely successful in the destruction of pathogenic microbes. Certain qualities of the microbes, the nature of the medium in which they must be destroyed, the vulnerability of the disinfecting agent itself, combine to place limitations on the effectiveness of disinfecting methods.

In livestock sanitary practice these restrictions are even more potent than in public-health work, owing largely to the greater abun-

dance of extraneous substances, of body wastes, and to the nature of the structures involved. Often an infected soil has to be considered, and inasmuch as soil is difficult to disinfect in an effective and yet economical manner, it must commonly be left to the slower methods of nature operating in the elimination of its disease-producing elements. Some forms of filth are difficult to disinfect and unless completely destroyed in some other manner their presence in a given environment would continue as a menace not to be disregarded.

The number of disinfecting substances is a formidable one, and new ones are launched every day. Many of these may be simply some well-established basic germicides disguised by a new name or by a new odor. The constant lauding of new disinfectants, apparent or real, may serve as evidence that a universally satisfactory disinfecting agent has not yet been found. Owing to the great variety of the conditions and circumstances under which disinfection must be accomplished, it is not to be expected that any disinfectant could possibly possess all the qualities which may be necessary for universal effectiveness.

General Considerations.—In order to bring about the destruction of the microbic causes of disease, various means are at the disposal of the sanitarian. When choosing between them he must be guided by the nature of the environment, by the character of the virus involved, and by the specifications and qualities of the agent to be employed. He must reckon with the factors which either hinder or enhance germicidal action; also such details as temperature and humidity must also be considered.

The question of costs enters into the problem, and not uncommonly the disinfector must modify his methods in order to adjust them to special requirements dictated by the nature of a given establishment or by business considerations. Not infrequently he will find himself constrained to combine different methods in order to achieve success.

The various means which may play a part in the technique of disinfection can be classified under the following groups: First, mechanical; second, physical; third, chemical.

Mechanical Means.—Cleanliness is fundamental to all disinfection. It is ordinarily brought about by mechanical means. Washing, scrubbing, scraping or dusting of soiled surfaces removes the filth in which pathogenic elements may be contained. The cleansing serves as a preparation by means of which the surfaces can be more readily subjected to disinfection proper.

A cleaning process may have little or no value as a means of dis-

infection but it may render it possible. However, the fact should not be overlooked that, as a result of mechanical cleansing, pathogenic elements, instead of becoming exposed to ultimate destruction, may be merely transported to places of safety. The water used for flushing a stable or the soapsuds applied to walls and equipment may serve as vehicles for the microbes. Unless such liquids can also be collected in a manner which permits their disinfection they should be used with caution and restriction.

The removal of filth in the dry state should therefore precede the washing, and even the distribution of dust must be avoided by the application of sufficient moisture to prevent its dissemination by air. The filth collected in this state must be carefully removed and destroyed.

After such a preliminary cleaning the washing, if necessary, can be done with a minimum amount of liquid, and this may have its cleansing powers strengthened by the addition of soap, soda or lye. When costs need not be considered the further addition of a compatible disinfectant would promote both safety and disinfecting efficiency.

The mechanical removal of contaminated filth must never be looked upon as more than a preliminary measure. *Per se* it has but a slight effect on the microbes against which disinfection may be directed. Without being followed by disinfection proper it can only bring about a removal of micro-organisms from one place to another.

The application of such substances as paint, tar or asphalt does not constitute disinfection, in the strict sense of the term, but may be resorted to on occasion if the surfaces do not lend themselves to complete disinfection. By this means, pathogenic germs may be imprisoned in the pores of a building material and there kept sealed in until their ultimate destruction. A coating of tar is often the only means by which a wooden floor can be rendered safe.

Physical Means.—So far as disinfection practice concerns the live-stock sanitarian, the employment of physical methods is almost wholly limited to the use of heat. Desiccation and radiant energy, no doubt, contribute to the salubrity of an environment, but they cannot be depended upon to meet hygienic requirements when a space has to be freed of pathogenic bacteria within a brief period.

The disinfectant action of heat is applied in many forms. As incineration and cremation it is one of the oldest methods of disinfection, and it continues to be a valuable method to this day. It constitutes the most effective means of disposing of polluted waste matters and carcasses and is, from time to time, even employed in the destruc-

tion of the cheaper sorts of shelter in the face of particularly virulent infections.

The use of hot water finds wider application, and in the routine cleansing of utensils in which animal products are handled, or which are used in the feeding of animals (dairy utensils, containers, pails, troughs, waterers, etc.), it is an important factor in the maintenance of a wholesome environment. Hot solutions of lye, soda and soap play a useful part in the pre-disinfection preparation.

The heat engendered when stable manure is tightly packed is usually sufficient to destroy the vegetative forms of most pathogenic bacteria which may be contained therein.

The heating of virulent or questionable foodstuffs is an every-day method of disinfection. It finds application most commonly in connection with milk to be used as food for young livestock. Two methods are in use: pasteurization and sterilization.

In pasteurization, the substance to be disinfected is exposed to a temperature ranging between 140 and 175° F. for periods ranging from a few minutes to one hour and a half. The lower the temperature, the longer must the exposure be continued in order to destroy the bacteria to be rendered harmless.

Pasteurization must be distinguished from sterilization. The latter aims to destroy all microbic life present; in the former only the vegetative forms of pathogenic microbes are killed. It may not always be sufficient to destroy spores, but in ordinary practice it is usually suitable to render a suspected or polluted milk quite safe for animal feeding.

After milk is pasteurized it must be rapidly cooled in order to prevent a growth of the saprophytic germs which may have escaped destruction.

The equipment required for pasteurization ranges between a simple container placed over a fire to the elaborate and complicated apparatus used in dairies and creameries. The former serves well when a few calves are to be protected against a possible infection by suspected milk. The heat must be controlled by the thermometer, the container should be covered, and the liquid should be agitated from time to time while the heating is in progress. Heating such milk to 150° F. for 20 minutes will render it quite safe in respect to the causative agent of tuberculosis, abortifacient disease and to the colon-typhoid intermediates.

Where pasteurization on a larger scale must be carried on as a routine practice, the process must always be carefully controlled, and

the more complicated the apparatus used for the purpose the greater will be the need of efficient supervision.

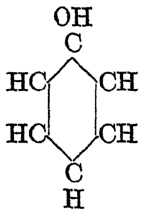
In sterilization, the substances or objects to be treated are heated to the boiling-point of water or even beyond (autoclave) for from 15 to 45 minutes or more. It is but rarely resorted to in livestock sanitation, but it occupies an important place in the disinfection of many objects in public-health practice.

Chemical Means.—The use of chemicals having a germicidal action is the method most commonly employed in the practice of disinfection as applied to livestock sanitation. They have practically become indispensable.

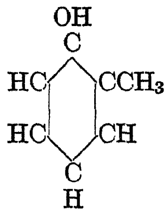
Chemical disinfectants often depend for their action on affinities of a chemical nature between the compound used and the component parts of the bacterial cell. The manner in which such affinities are satisfied is, in part at least, quite unknown. The atomic composition of the molecule of disinfecting chemical exercises an influence on germicidal action which is difficult to account for.

Thus in the case of the aliphatic alcohols, bactericidal action increases with the number of carbon atoms forming part of the molecule. Amyl alcohol ($C_5H_{11}OH$) is more active than ethyl alcohol (C_2H_5OH), and the latter excels methyl alcohol (CH_3OH) in germicidal qualities.

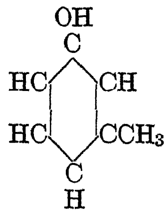
Even the molecular architecture of certain closely related compounds exercises an influence on their germicidal value. This is manifested by the difference shown by the three isomeric cresols. Cresols are formed when one or more of the nuclear hydrogen atoms of phenol are replaced by a methyl group. The cresols not only excel phenol in disinfectant powers but they differ *inter se* in accordance with the ortho-, meta-, or para-position of the methyl groups, as shown by the following:



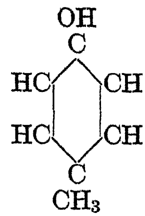
Phenol (C_6H_5OH)



Ortho-cresol ($C_6H_4OHCH_3$)



Meta-cresol ($C_6H_4OHCH_3$)



Para-cresol ($C_6H_4OHCH_3$)

Of the three isomeres the para-cresol exceeds the meta-cresol in germicidal power, and the meta-cresol exceeds the ortho-cresol.

The better-known modes of action of the various disinfectants are caused by osmotic changes (hydration and dehydration), precipitation of colloids of the bacterial cells by such action or the direct precipitation of protein substances which enter in combination with the disinfectant. Other substances exercise a lytic action on the germ cell, and oxidation of the organic substances contained in the latter is the basis of action in another group.

In the case of the so-called electrolytes, physico-chemical influences determine disinfectant action. These are chemical substances which, in watery solution, split in two component parts, the electrically positive cation and the electrically negative anion. The number of both groups of ions or, in other words, the degree of dissociation determines the disinfectant action, and all influences which tend to restrict this dissociation, in a measure, hinder germicidal action. Such an inhibitory influence may be observed if an electrolyte disinfectant is dissolved in a solvent in which dissociation is less active than in water; this explains why the germicidal powers of solutions of such substances in oils, alcohol, etc., are materially less than their aqueous solutions.

The degree of solubility of a disinfectant in water is a potent factor in determining its germicidal action. A high degree of solubility enables the disinfectant to attain the degree of concentration necessary to display its maximum toxicity toward the bacterial cells.

For a maximum germicidal action, contact must thus be made in aqueous media by which the various ingredients are carried to the germ cells. The nature of the latter also is a determining factor. As a general rule, the presence of extraneous matter in the medium tends to hinder germicidal action.

The temperature of the medium in which the interaction between disinfectant and bacteria must take place materially affects germicidal action. As in other chemical reactions, a higher temperature enhances both speed and intensity of action. An increase of 20° F. may double or treble germicidal power, and with certain disinfectants such a thermic influence may intensify this power eightfold. In this connection it is important to remember that, at the lower temperatures, most germicidal action is naturally impaired. At a freezing temperature the action of many disinfectants may be entirely suspended.

Microbic characters also exercise an influence on germicidal action. The size of the bacteria, their structure, component parts, and their nature, constitute variants which help to determine their behavior toward a given disinfectant.

DISINFECTANTS

The number of chemical disinfectants, or of alleged disinfectants, now offered for sale is so enormous that even to name them would be an impossible task. Nor would it be relevant to do so, because many of the substances sold as disinfectants are only variants of well-known and thoroughly established germicides to which a resounding name has been given and which have been made distinctive by the addition of inert odoriferous or coloring substances. Hence, only the disinfectants more commonly employed and designated by their official names will here be given consideration.

Although the ideal disinfectant efficient under all conditions is as yet a chimera, it seems proper to enumerate the qualities which contribute to make a germicide suitable for practical purposes. They are: (1) a high degree of disinfectant power in minimum concentration at lower temperatures; (2) freedom of qualities injurious to objects to be disinfected; (3) a minimum degree of toxicity for man and livestock; (4) a maximum of chemical and physical stability; (5) a ready solubility in water; (6) absence of vile or lingering odors and objectionable coloring qualities; (7) availability at minimum cost, and (8) fitness for safe and ready transportation.

The disinfectant power of a given germicide is commonly expressed by its phenol coefficient, which denotes the degree of germicidal action as compared with that of standardized dilutions of phenol. The comparison is made under identical conditions, and the coefficient is based upon the average result of several tests. This coefficient is only a relative indication of disinfectant action, but it constitutes a useful base to evaluate a given germicide. A low coefficient indicates inferiority, but the reverse is not always true, owing to influences met in practice which cannot always be adequately represented in a laboratory technique.

The disinfectants generally employed in livestock sanitary practice may be chosen from one or more groups. These may be inorganic or organic compounds. The former include oxidizers or electrolytes; the latter embrace representatives of the aliphatic and aromatic series.

Oxidizers. *Potassium Permanganate* ($KMnO_4$).—This is an active disinfectant owing its germicidal power to the nascent oxygen. In a 4 per cent solution it kills anthrax spores in 40 minutes. The addition of hydrochloric acid materially enhances its germicidal action, and anthrax spores are killed in 2 minutes by a 1 to 2 per cent

solution of the permanganate to which 0.9 per cent of the acid has been added. A 1 per cent solution of the potassium salt kills the glanders bacillus in 2 minutes. Permanganate of potassium is soluble in 16 parts of cold water and in 2 parts of boiling water.

In spite of these manifest qualities it is but rarely used in practice. Its cost is relatively high, and its germicidal action is greatly impaired or entirely neutralized by the presence of organic matter. A further disadvantage of this otherwise potent bactericide is associated with its property of staining objects a deep brown color. Its application is limited to the disinfection of water troughs in which a remnant of contaminated water must be rendered harmless.

Chlorine.—The gas chlorine is a powerful germicide, its action depending upon its marked affinity for hydrogen. In the presence of light it readily combines with the hydrogen of water, setting free the oxygen which, in its nascent state, is destructive to microbe life.

The gas will kill micro-organisms in dry air if present at the concentration of 5 parts per 1000, but in moist air, one-eighteenth of this amount is equally active. Chlorine is heavier than air; if used as a disinfectant the supply should enter the space to be disinfected from above.

The gas can be obtained compressed in metal cylinders or it may be prepared by the decomposition of a hypochlorite by sulphuric acid. One and a half pounds of the hypochlorite of lime acted upon by 6 ounces of sulphuric acid will yield a quantity of gas sufficient to fumigate a space of 1000 cubic feet.

In spite of its potent germicidal action, gaseous chlorine is but rarely used in the practice of disinfection. It is extremely irritating and destructive to many substances and to pigments. A further disadvantage, shared with other gaseous disinfectants, is that its action is practically confined to the surface. Its use is almost entirely limited to the disinfection of drinking water. Combined with other elements, however, chlorine finds a much wider application.

Chlorinated lime or calcium hypochlorite is one of the earliest germicides known, and as such it antedates the knowledge of the microbic origin of disease. Calcium hypochlorite, also known as "bleaching powder" or "bleach," is prepared by the saturation of slaked lime with chlorine gas. The molecular structure and the exact nature of the chemical composition are not precisely known. It varies in its composition and may be represented as $Ca(OCl_2)$ or $ClCaOCl$, or $Ca(ClO)Cl$. It is now generally accepted that of dry chlorinated lime the calcium oxychlorid ($CaOCl_2$) is the most active ingredient,

and that in solution the calcium hypochlorite is the source of the disinfecting chlorine.

Chlorinated lime is soluble in about 20 times its weight of water, but it leaves an insoluble deposit composed of calcium hydrate. "Bleach" should contain from 30 to 35 per cent of chlorine, and upon the latter its disinfectant action must depend.

The hypochlorite of calcium is a useful germicide; in a 20 per cent suspension it kills anthrax spores in 1 minute. The vegetative forms of bacteria are usually destroyed within the same length of time in a 1 to 100 suspension in water. The tubercle bacillus, however, is more resistant. Like most disinfectants depending upon the presence of nascent oxygen the bactericidal action of chlorine preparations is rapid and very transitory, continuing only as long as the decomposition has not been completed.

"Bleach" is used in watery suspension as well as in the form of dry powder. It is particularly useful in the disinfection of drains, sewage and feces. It must always be used in quantities in excess of apparent requirements because of its liability to be rendered inert by the presence of organic matter.

It was shown that a preparation containing 10 per cent of available chlorine had a phenol coefficient of 21, but when mixed with an equal volume of urine the coefficient had become reduced to 0.8 within a period of 1 hour.

Chlorinated lime has some of the disadvantages of free chlorine. It is very destructive to colors and is apt to damage fabrics and leatherware; its odor is readily taken up by milk and meat.

Electrolytes. *Sulphuric acid* (H_2SO_4) is an active germicide which in relatively high dilutions still may constitute a good disinfectant. A 1 to 2 per cent solution will destroy the vegetative forms of most bacteria within the space of 1 hour. Anthrax spores are more resistant, and for their destruction a more concentrated solution would be required. The acid is very destructive to most objects and especially to metals. Its manipulation in the course of preparing the required dilution is not always without danger, and for this reason also its general use cannot be recommended. In the crude, commercial form, the acid is cheap, and for this reason, as well as for its effectiveness, it is occasionally used in the disinfection of waste matters, such as manure, sewage, and other filth.

Sulphur Dioxide (SO_2).—A gas obtained by the combustion of sulphur. Though extremely useful in the destruction of insects, rats, and other pests, its value as a disinfectant is very slight and has always

been greatly overrated. It requires the presence of water in order to develop whatever germicidal powers it may have, and in reality these are entirely due to the sulphurous acid (H_2SO_3) which results from the combination of the oxide with water. The dry gas is practically without bactericidal qualities. Even in the presence of moisture, sulphur dioxide has but poor penetrating powers. It attacks metals, fabric and coloring matters.

If used at all, it may be applied as gas or in aqueous solution, the water, when cold, taking up more than 30 times its volume of the dioxide. The gas may be obtained and compressed to the liquid state in metal drums. In that form its use is too costly for ordinary disinfecting purposes as about 10 pounds would be required for every 1000 cubic feet to be disinfected.

If used for stable disinfection the so-called pot method of generation is to be preferred. One or several cast iron pots are placed in wash tubs partially filled with water, and the sulphur, in rolls, is stacked in the pots. A small quantity of fuel alcohol is sprinkled on the sulphur and the whole ignited. Five pounds of sulphur are required for every 1000 cubic feet of space, and the exposure should be prolonged for not less than 6 hours.

Sodium hydrate (NaOH) has, in applicable concentrations, but a slight germicidal action, however destructive it may be to all organic substances in the more concentrated solutions. Its chief value in disinfecting practice is limited to the preliminary cleansing process.

Sodium carbonate or soda (Na_2CO_3) may also be used dissolved in water, as a cleansing agent, but it has little or no disinfecting value.

Calcium hydroxide (Ca(OH)2 is a time-honored disinfectant prepared by the slaking of calcium oxide or quick lime. Laboratory tests have confirmed its old reputation as a germicide. Most bacteria in their vegetative forms are destroyed by a 1 per cent solution within a few hours, and a 20 per cent suspension added to equal parts of feces or other organic filth and well incorporated with the mass will disinfect it within 1 to 2 hours.

For disinfecting purposes, quicklime must be freshly slaked, for the absorption of carbon dioxide from the air renders the lime inert by changing it to the inactive carbonate. In the process of hydration, heat develops, and this adds to the germicidal effectiveness. For the disinfection of moist substances, like feces, urine, sewage, the quicklime is added to the mass and mixed with it so that the slaking and heating take place within the latter.

Mercuric chloride or sublimate ($HgCl_2$) is a powerful disinfectant; even in relatively weak solutions it is destructive to most biologic forms. It is soluble in 16 parts of cold water and in 3 parts of boiling water.

Mercuric chloride is acted upon by many substances which may be present in the medium in which microbic elements must be killed. This is the principal reason why, in spite of its active germicidal properties, its value as a disinfectant is ordinarily greatly overestimated. It precipitates albuminous substances, and its disinfecting power is largely neutralized by their presence. It is further rendered inert by the caustic alkalies and by sulphides present in putrid materials ($(NH_4)_2S$), and for these reasons its use is contra-indicated for the disinfection of media which are rich in organic substances, and all the more so if they are alkaline in reaction. To these disadvantages must be added the one of marked toxicity for man and animals (bovines especially), as well as its affinity for metals in general.

Sublimate is usually applied in solutions of 1:1000, but when spores are to be destroyed a hot solution of 1:500 is to be preferred. The required solutions are most conveniently prepared from the compressed tablets generally available in the trade. Concentrated solutions are also used as a stock supply; the addition of a small quantity of hydrochloric acid will render such a stock more durable.

Aliphatic Series. *Formaldehyde* (HCOH).—Formic aldehyde is formed by the incomplete oxidation of methyl alcohol. It consists of a colorless gas of a pungent, irritating odor. This gas has a density approximating that of the atmospheric air. It is soluble in water and under the name of formaldehyde solution or formalin, containing 40 per cent of the gas, is most readily made available.

The gas polymerizes readily at the lower temperatures, forming either the waxy insoluble para-formaldehyde or trioxymethylene, which, under the influence of heat, again yields the formaldehyde.

Formaldehyde is an excellent disinfectant and all the more valuable because it is not rendered inert by the presence of albuminous substances. It is not very poisonous and has no injurious effect on the objects usually to be exposed to its action.

By its tendency to polymerize the solution is rather unstable, but the addition of about 10 per cent of methyl alcohol tends to reduce this disadvantage.

The germicidal power of formaldehyde is brought about by the coagulation of the proteid components of the bacterial cell. In contact with the skin it hardens the latter; in the higher concentrations

the substance has a caustic effect, which can, to some extent, be mitigated by the addition of soap to the solution without impairing its bactericidal action.

As a general disinfectant, formaldehyde is superior to mercuric chloride, which is rendered inert by albuminous matter and other ingredients of the media to be treated. A 10 per cent solution of formalin is approximately equivalent to a 0.2 per cent solution of sublimate and it develops a greater disinfectant action than a 5 per cent solution of phenol.

The antiseptic, bactericidal and sporocidal values of formaldehyde are not proportionate to its degree of concentration. Although a higher concentration may relatively shorten the period required for disinfection it is not economical to employ the stronger solutions inasmuch as this germicide is comparatively slow in its action and in any degree of concentration a certain time of exposure would be required for the completion of the process.

Formaldehyde inhibits bacterial growth in dilutions of 1:10,000. In a 1 per cent solution most bacteria succumb within 1 hour. Acid-fast organisms are more slowly destroyed. Whereas the vegetative forms of the anthrax bacillus are killed in 5 minutes by a 1 per cent solution, the spores of this organism require for their destruction an exposure of 1½ hours to a solution of from 12 to 15 per cent. However, the spores dried on silk threads were killed when submerged for 1 hour in a solution at from 2 to 5 per cent, and in 10 minutes in a 10 to 20 per cent solution.

When used in liquid form a 10 per cent solution of formalin is sufficient for practical purposes. Formaldehyde is an excellent deodorizer, and fecal matter is deprived of its odor almost instantaneously. If such a material be thoroughly mixed with a 10 per cent solution and left in contact for a period of not less than 1 hour, the disinfection will be found to be complete.

The gas formaldehyde is commonly used as a fumigant, but its action, like that of other gaseous disinfectants, is not a penetrating one and is largely confined to the surface of the object exposed. Its germicidal action is further impaired by low temperatures and by lack of humidity. If the temperature of the space to be fumigated is below 65° F. and its relative humidity less than 60 per cent, disinfection results become uncertain. At temperatures below 50° F. the gas becomes unreliable as a germicide and especially so during dry weather. For the best results, moisture must be made available, and during cold weather the space to be disinfected should be heated.

Owing to the slowness of its action, exposure should be prolonged to from 6 to 12 hours. The diffusibility of the gas renders a complete sealing of all openings quite necessary.

In disinfection practices in which formaldehyde is used in its gaseous form, the disinfectant may be generated from the solution or from its polymeric forms by the application of heat. More simple is the sheet method. For this purpose a sheet measuring 2 by 2½ yards is thoroughly sprinkled with formaldehyde solution without causing it to drip and suspended in the space to be treated. The amount of gas thus liberated is sufficient for a space of 1000 cubic feet.

More convenient is the potassium-permanganate-formalin method. For the fumigation of 1000 cubic feet of space, 500 c.c. of formalin is placed in a pail, or similar receptacle, and to this 250 g. of the permanganate is added. An active oxidation with generation of heat takes place during which the gas is liberated.

The formalin-lime-aluminum-sulphate method also depends on the heat generated by the reaction. The following ingredients are required for each 1000 cubic feet of space to be disinfected. A solution of 150 g. of aluminum sulphate in 300 c.c. of hot water; 600 c.c. formalin and 2000 g. of quicklime. The aluminum sulphate and formaldehyde solution are mixed and poured upon the lime in a suitable container, such as a large pail.

The irritating character of formaldehyde constitutes a disadvantage requiring prompt and rapid application. Formaldehyde is harmless to most objects, but it should not be used for the disinfection of leatherware, because the latter is rendered brittle when in contact with the disinfectant and may thus become permanently damaged.

Aromatic Series. *Carbolic Acid.*—Although this name is commonly applied to the alcohol phenol, it is more applicable to a more or less variable mixture largely consisting of phenol and phenolic bodies. All these substances are coal-tar derivatives, and hence the so-called crude carbolic acid was often erroneously designated as "coal-tar creosote."

The crude carbolic acid of commerce is a mixture of phenol and the isomeric cresols and in addition contains coloring matter and impurities. It is partially soluble in 15 parts of water at 15° C., and the undissolved residue should not exceed 10 per cent of its volume.

Crude carbolic acid, owing to the cresols which enter into the compound, has a higher germicidal value than pure phenol. Its phenol coefficient is about 2.75. Hence it is useful in the disinfection

of certain stables, floors, pens and other parts where its disagreeable odor and staining qualities cannot be objected to. It is applied in a 5 per cent solution preferably made with hot water.

Phenol (C_6H_5OH).—As already stated, phenol is a coal-tar derivative. It is a rather weak germicide and especially known because of its introduction as a surgical antiseptic by Lister, when he ushered in the operative surgery of today. Although but little used in sanitary practice it has retained a certain significance because of its adoption as the standard in the determination of germicidal values. Aside from its inferiority as a disinfectant, it has the further disadvantages of unpleasant odor and toxicity. On the other hand, it has a marked chemical stability and is but little interfered with by albuminous substances. Upon the latter quality depends its wide application as a preservative for sera used in immunization practices.

Phenol is suitable for the disinfection of fabrics, for which a 3 to 5 per cent solution permitted to act for 1 hour is effective. However, it does not destroy spores and is quite inactive in the destruction of the filterable viruses. In sanitary practice, phenol has been almost entirely displaced by the isomeric cresols.

The cresols ($C_6H_4OHCH_3$) are formed when one of the nuclear hydrogen atoms of phenol is replaced by the methyl radicle CH_3. According to the position of the latter group, ortho-, meta-, and para-cresols may be distinguished. What is commonly included under the name "cresol" is a mixture of the three isomeric cresols.

The cresols are quite superior to phenol as germicides. They are but sparingly soluble in water, but are readily dissolved in soap solutions, a quality which is the basis for the many proprietary cresol preparations of commerce. It is quite doubtful if any of the latter are materially superior as disinfectants to the official cresol compound known as liquor cresolis compound.

Liquor cresolis compound U. S. P. is composed of the following ingredients: Cresol 500 g., linseed oil 350 g., potassium hydrate 80 g. and water *q. s.* for 1000 g. In the absence of organic matter it has a phenol coefficient of 3.00, and in the presence of organic substances its coefficient is 1.87.

This, as well as some others among the saponified cresols, is an effective disinfectant in solutions of from 1 to 4 per cent. This germicide is less toxic than phenol, but it has the disadvantage of soapiness and of the odor common to the group.

Practical Applications.—Although it is quite probable that the value of disinfection as commonly applied is tremendously over-

estimated, it must be conceded that the practice may, on many occasions, contribute to the salubrity of an environment. However, the very nature of the environment, its extent, and degree of contamination are often such as to preclude a complete elimination of any virulent microbes which may have found lodgment in it.

Disinfection may be concurrent or terminal. The former, in which the virulent material of the immediate surroundings of a sick animal is destroyed every day, is, no doubt, the most apt to be productive of desirable results. This has its foundation on the fact that the further removed in space as well as in time from the primary infection source, the less efficient disinfection becomes.

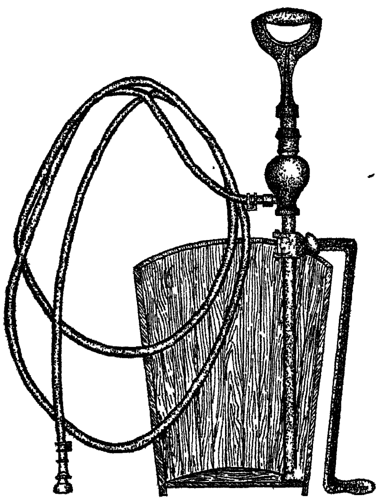


FIG. 66.—A spray pump suitable for stable disinfection.

The concurrent daily disinfection has the advantage of promptness and may be assumed to prevent contamination of a greater part of an environment. In live-stock sanitary practice, concurrent disinfection is not as commonly attempted as its usefulness warrants. The costs and the lack of a trained personnel are obstacles which account for a degree of apparent negligence in this connection.

Terminal disinfection is more frequently applied, although it may often be compared with the locking of the stable door after the horse has been stolen. The practice pertains to the disinfection of the surroundings after recovery, death, or removal of the infected animals. It may be designated as deferred disinfection and hence frequently undertaken after the microbic factors of disease have been scattered over a large area or have been transported to the more remote portions of an environment where they are apt to escape their intended destruction.

Disinfection, if to be of value at all, must be done with a high degree of thoroughness and should never be looked upon as a mere final ritual in the calamity of disease. A shallow, perfunctory disinfection is often worse than none at all and as such it may amount to a mere waste of time and material.

Stable Disinfection.—The disinfection of a stable should always be

preceded by the removal of all waste matter and filth. Such bulky material as stable manure may have to be disposed of in suitable places where it can be safely stored, or, still better, where it can be completely destroyed by fire. If the stable filth is less voluminous in character, it may be kept within the stable and there thoroughly mixed with hypochlorite of lime and moistened, or it may be treated with a strong formaldehyde solution, covered by a tarpaulin and left exposed to the disinfectant for from 12 to 24 hours. All utensils used in the handling or transportation of such substances should, in turn, be subjected to disinfection.

It is imperative that, during the process of cleansing, sweeping or scraping, the dissemination of dust be prevented. For this purpose the objects to be cleaned may be slightly moistened, preferably with a suitable disinfectant solution.

Although in the preliminary cleansing, the use of an abundance of water or of soap and soda solution is commonly recommended, the practice may be accompanied by a certain hazard of removing virulent material to some other place where it may escape destruction in the final phases of the process. The less infective materials are scattered, the more effectively can the microbic elements be destroyed.

In stables of solid construction, where it is possible to collect the fluids used in washing down the various parts, there is, of course, no valid objection to this mode of cleansing. If the fluids used can be applied hot, this would constitute a decided advantage.

In the pre-disinfection preparation all detachable parts must be removed. They may be separately treated, or such objects as mangers or hay racks may be disposed of by burning.

After the preliminary cleansing and the removal of worthless parts, the stable may be treated with such disinfecting solutions as formaldehyde (10 per cent), hypochlorite of lime (10 per cent), or liquor cresolis compound (4 per cent). These solutions may be sprinkled over the various parts or applied by means of a spray pump. No portion of the surface should escape adequate treatment.

Open drains and cesspools should be treated liberally with "bleach," and this should be done before the contents are permitted to drain away. Stable utensils, such as pails, shovels, forks, grooming tools, and the like, must also be included in the process. Harness and other leatherware and ropes should be immersed for 12 hours in a 2 per cent solution of liquor cresolis compound, dried and greased. Stuffed or upholstered equipment, such as saddles, may be injured by immersion, unless so made as to be water-proof. If not water-proof,

such objects may be washed with the disinfectant, dried, and the leather parts covered with a thick layer of grease. The whole can then be suspended in a formalized atmosphere for the destruction of virus in the stuffing.

Owing to the difficulty in securing tightness of the stable space, the gaseous germicides have but little application in stable disinfection. If used at all, formaldehyde is to be preferred as the most efficient.

Earth floors cannot be adequately disinfected. If polluted, at least 4 inches of the surface should be removed, disposed of in some safe place and be replaced with fresh, clean earth or, still better, by concrete construction.

The plank floors still frequently met with are most difficult to disinfect owing to their seams and cracks. They should be treated with a second application after having become dry after the first treatment, and even regardless of this precaution, it is often advisable to cover them with a thick coat of coal tar in order to seal in any microbic elements which may have escaped destruction.

Railway cars, ships and paddocks may be disinfected by any of the methods applied to stables.

The garments of stable attendants must often receive attention. If they consist of linen or cotton fabrics they are best disinfected by submersion in a solution of phenol (3 per cent) in hot water for from 6 to 12 hours. Woolen garments may be suspended in a closed locker and there exposed to formaldehyde fumigation. Shoes and boots are to be submerged in a solution of liquor cresolis compound (2 per cent) for from 6 to 12 hours.

Remnants of contaminated drinking water in troughs or other containers should not be evacuated on the premises before being rendered safe by the addition of 1 pound of "bleach" to every 5 gallons of water. This should be well mixed and then left undisturbed for not less than 6 hours.

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CHAPTER XIII

DISINFESTATION AND DISINFESTANTS

THE presence of various biologic forms other than the pathogenic microbes is, or may be, detrimental to environmental salubrity. The majority of these are arthropods, but such mammals as rats and certain mollusks, serving as hosts to disease-producing trematodes, also have a hygienic importance.

Their destruction or abatement may be designated as disinfestation. Inasmuch as the technique and means employed in disinfestation may greatly differ from those used in the practice of disinfection, it seems fitting that the subject be considered quite detached from the latter.

The two subjects differ especially in one respect, namely: that disinfestation cannot be confined to the environment alone, however much they may otherwise have in common. Disinfestation must often be extended to the animals themselves. The latter more than disinfection is apt to supply therapeutic measures as well as preventive ones in one and the same effort.

MEASURES OF CONTROL

The biologic forms which, as parasites, semiparasites or vectors of transmissible diseases render their destruction or control necessary, vary so widely in their nature that the means useful against them must commonly be chosen for each specific case. In a number of these, no methods of control have as yet been accepted as adequate. In others, certain measures are effective which are of no value against some other pest.

At a certain season an infesting species may be quite vulnerable and yet be entirely exempt from molestation during the remainder of the year, whereas other species may be open to attack whenever and wherever they present themselves.

The methods of disinfestation thus must vary in accordance with the problem to be faced, or different methods must be combined in

order to secure maximum results. Certain methods are adequate and safe during a given season but must be rejected in another.

Although it is not possible to narrowly classify the available methods of disinfestation, it is convenient to arrange them in the following groups: (1) physical or mechanical disinfestation, (2) legal control measures, (3) chemical disinfestation, and (4) biological control measures.

Physical or Mechanical Disinfestation. *Manual Disinfestation.*—If the term disinfestation is applied in its broadest sense, it must include all measures which tend to hinder infestation and which interfere with the life habits and propagation of offending pests. Thus there is justification for naming the practice of grooming as a more or less effective deterrent to a number of biologic forms. It does not destroy the invaders, but is prone to place limitations on such parasites as lice, fleas or ticks. The removal of the hair coat by clipping or shearing, considered in another chapter, has the same tendency.

Hand picking of infesting arthropods is a more radical measure, but has a rather limited application in livestock sanitary practices. The method is resorted to in the case of certain ticks when present in limited numbers or on certain circumscribed areas of the animal body. The removal of screw-worm maggots may also be accomplished by merely mechanical means although the method is usually supplemented by the use of chemical disinfestants.

In one instance, however, manual disinfestation is the most effective method of control and that is in the case of the two species of *Hypoderma*, the larvae of which, at a definite time, present in the dorsal subcutis of their hosts, are available for mechanical removal and destruction.

Mechanical devices include the protection of stables by screening and of animals by fly nets or other coverings. Such measures are only palliative and at the best are instrumental in bringing comfort to the animals. Certain types of nose bags, or modifications thereof, have a value as a protection against the ovipositing of the nose bot fly (*Gastrophilus hemorrhoidalis*).

Traps are successfully applied as a radical measure in rat extermination. Many ingeniously designed traps have been proposed for this purpose but commonly have brought disappointment. The simple spring trap or "break-back" trap has been shown to be the most effective.

Fly traps are used as supplementary means to cope with fly pests

about stables or out in the open where blow-flies constitute a problem. Great quantities of flies may thus be secured for destruction, but on the whole, traps have not become popular where the fly problem has a livestock sanitary aspect. Within stables and other enclosures, traps, no doubt, will reduce the number of flies present, but out on pastures or ranges, the number of flies caught will be small in comparison with the available supply.

Thermic Measures.—The superheating of spaces in which insects are to be destroyed may prove to be an effective means of disinfestation. Experimental evidence shows that insects cannot withstand high temperatures for prolonged periods. Exposure to temperatures of 140° to 150° F. will destroy most insects within a space of four hours. The method can best be applied during the hottest days of summer. Its use is obviously of limited application and has thus far not been used in livestock sanitary disinfestation.

Environmental Amelioration.—The nature of immediate surroundings may be a potent factor in determining infestation in a qualitative as well as a quantitative aspect. It may offer hiding places and shelter to the biologic forms concerned and it may have properties quite essential to their propagation. The removal of environmental qualities which tend to promote infestation or to offer protection to the forms involved certainly has a definite place among disinfestation measures.

Constructional factors have been described in another chapter. In dealing with the larger infestants such as rats, a certain type of construction is probably of more direct value than any other measure. Rat-proof buildings, by the means of which rats and their food and shelter are kept separate, have a disinfesting value of the first order. It is much easier to build rats out than to exterminate them after the animals have secured ingress.

Constructional considerations, likewise, have weight in efforts to deal with such parasites of poultry as *Dermanyssus gallinae* and *Argas persicus* (Oken). These ticks seek the shelter of seams and joints during the daytime and attack the fowls at night. Hence it is more essential to destroy them in their hiding places than on the bodies of their hosts. This disinfestation is more readily accomplished by seamless construction of the building itself and by providing dismountable equipment by means of which the favorite hiding places can be exposed to the action of killing substances.

Drainage.—Swampy lands, wet meadows, and quiescent bodies of shallow water serve as breeding grounds for such infestants as mos-

quitoes and horse-flies, and for the snails essential in the propagation of distomatosis. Hence the amelioration of the environment by drainage constitutes an important measure in the control of these pests.

Weed eradication as well as the removal or disposal of crop residues tends to deprive certain flies of their hiding places. Tall weeds and shrubs are factors which tend to aggravate such pests as the sheep nose fly (*Oestrus ovis*), and if the removal of such shelters is not possible, they should at least be avoided when pasturing sheep in daytime during the fly season. The burning of grass and other vegetation of the veld or range has a certain value in tick eradication if combined with other methods. Burning alone will not eradicate these pests, but will be helpful in reducing their numbers.

The disposal of wastes, such as manure and other decomposing substances, is essential in the control of the house fly and the stable fly (*Musca domestica, Stomoxys calcitrans*). It is helpful in abating the rat nuisance, and the removal and burning of the litter of the bedding grounds of scabby sheep and cattle are essential measures in the prevention of scabies.

The adequate disposal of carcasses is the most dependable method of abating the various blow flies.

Farm and Pasture Practices.—The fact that certain arthropod infestants require a sojourn off the animal body and on the soil for egg laying and hatching renders pasture rotation an essential part of the scheme of eradication. This is particularly the case of the many species of ticks. When infested areas are devoted to crop growing or are abandoned by livestock, the seed ticks are doomed to perish through starvation. The details of this method of disinfestation will receive more detailed consideration later in this chapter.

Sanitary Police Control.—The exercise of the police power of government involves the enforcement of quarantine measures which tend to prevent the introduction of new infestants in a given state or country, or to confine them to certain areas. Such measures proved to be extremely useful in the prevention of the extension of Texas fever to the northern stock ranges of the United States by the movement of tick-infested southern cattle. They practically removed the fever hazard from a large area.

DISINFESTANTS

In the eradication and control of noxious arthropods and other biologic forms for sanitary purposes it is commonly necessary to have

recourse to chemical agents which, when introduced into the bodies of such infestants, exercise a toxic action, or when made to cover the body surfaces mechanically obstruct the air passages.

The action of intoxicants is similar to those which are poisonous to higher forms. It depends principally on an interaction between the poison and the protoplasm of the body cells. Such an interaction gives rise to the formation of new substances incapable of playing a part in the biochemic processes upon which life is dependent.

All substances which either by chemical or by mechanical action tend to destroy the various infestants of hygienic importance may be designated as disinfestants. They vary greatly in character as well as in mode of action, and it is difficult to subject them to a logical classification. Following the practice of entomological authors, the various disinfestants which may be useful in livestock sanitary practice may be divided into the following groups: first, alimentary poisons; second, contact poisons; third, fumigants; and fourth, repellents.

This grouping is more a matter of convenience in description than a classification based upon outstanding qualities which characterize the various substances. Some of the substances could be logically included in more than one group; the classification of others is entirely based upon opinion empirically formed, for their mode of intoxication is as yet undetermined.

Alimentary Poisons.—Alimentary or stomach poisons are toxic substances taken into the digestive tract of the infestant, although they may as readily exert their lethal action when introduced through the respiratory tubes.

Arsenic and Arsenicals.—Arsenic and its compounds are highly toxic to all animals and have been used for centuries for the poisoning of rats and other noxious animals. Many preparations of arsenic have been designed for the purpose. They are now less frequently used as rat exterminators, having been displaced by other chemical disinfestants.

Their use in livestock sanitary practice is generally confined to baths designed for the destruction of ticks, mites and lice present on the body of the domestic animals. For this purpose they are highly effective and are conveniently handled and transported, but owing to a high degree of toxicity the use of arsenical dips requires adequate supervision and caution.

The base for such stock dips as are now generally used is the so-called white arsenic or arsenic trioxide, or arsenious oxide (As_2O_3).

It is soluble in water, arsenious acids forming in the solution. In the presence of basic substances, arsenites are formed, and these are commonly desired as the active principle of the disinfestant solution. By the addition of sodium hydrate or sodium carbonate the arsenite is readily formed. Or the sodium arsenite is added to the dips as such.

The quantitative composition of arsenical dips varies with the object in view, with the type of animals to be treated, and as dictated by local opinions and experience.

The dips used in the United States for the eradication of cattle ticks are prepared in the following manner.

Two formulas are proposed for field dips and are designated as the "self-boiled dips (S-B dip) and the boiled dips." The principal difference between the two is that the heat required for the preparation of the former is produced by chemical action, whereas for the latter it must be provided with the aid of fire.

For the preparation of the S-B dip, two stock solutions are compounded. Solution A or the arsenic stock solution contains caustic soda 4 pounds, white arsenic 10 pounds and sodium carbonate crystals 10 pounds. The 4 pounds of caustic soda are dissolved in a gallon of water and while the solution is still hot the 10 pounds of arsenic are slowly added, care being taken to maintain a maximum temperature without causing the solution to boil. When these ingredients have been completely dissolved, the solution is diluted to 4 gallons and the sodium carbonate is added and caused to dissolve by agitating the mixture. After cooling, enough water is added to bring the volume of the solution to five gallons.

Solution B or the tar stock is made by slowly adding 1 gallon of pine tar to a solution of ¾ pound of caustic soda in 1 quart of water.

Of solution A, 1 gallon is added to every 125 gallons of the bath, and of solution B, 1 gallon is to be added to every 300 gallons of the dip in the vat.

The addition of tar to the bath is said to increase the wetting power of the solution and reduces the danger of injury to the skin by the arsenite. It causes the dipping fluid to adhere better and to prolong its action after the animals have passed through the tank. The tar in the vat also tends to keep the animals from drinking the fluid.

The boiled dip contains 24 pounds of sodium carbonate crystals, 8 pounds of white arsenic and 1 gallon of pine tar. The sodium carbonate is first dissolved in 25 gallons of water in a tank heated

over a fire. After the sodium carbonate has completely dissolved, the arsenic is added and brought into solution by stirring. The mixture is then permitted to cool to 140° F. when the tar is slowly added under constant stirring. The quantity thus prepared is sufficient for 500 gallons of bath ready for use.

The first bath thus prepared contains about 0.19 per cent of arsenious acid; while in use the solution must be controlled by periodic tests so that the actual content of arsenious acid does not become less than 0.175 per cent.

In dipping operations under official supervision proprietary arsenicals are permitted provided that the strength of the prepared bath corresponds to the specifications mentioned above. The supervising inspectors are provided with a testing outfit to control the arsenic contents of the bath fluid while dipping operations are in progress.

The arsenical dips prescribed by Australian governments correspond to the one in use in the United States. Four hundred gallons[1] of the prepared dip contain the following ingredients: 8½ pounds of arsenic trioxide, 4 pounds of caustic soda, ½ gallon of Stockholm tar and 4 pounds of tallow. The ingredients are divided over two stock solutions A and B. In solution A, half the amount of the caustic soda is dissolved in 4 gallons of water, and in this solution the arsenic is also dissolved with the aid of heat. In solution B the remainder of the caustic soda and the tallow are boiled together in water, the tar being slowly added after the solution has been completed. The two stock solutions are then added to the bath in the proportions mentioned.

The above-mentioned formula corresponds to the one known as Queensland Cattle Dip A. A variation of the latter is Queensland Cattle Dip B, which, when fully prepared, contains in every 400 imperial gallons, 8 pounds of arsenious acid, 4 pounds of caustic soda and 1 gallon of bone oil.

The arsenic contents of the New South Wales dip is the same as the one mentioned above but varies in that it is mixed with 12 pounds of washing soda, 2 pounds of common hard soap and from ½ to 1 gallon of Stockholm tar.

The arsenical dips used in South Africa vary in strength in accordance with the frequency of the dipping operations. These dips were proposed by Pitchford in Natal, who designed them for dipping

[1] The gallon current in Britain and the British dominions is the imperial gallon.

intervals of 3, 7 and 14 days. They are prepared in accordance with the following formulas:

Ingredients	3-day intervals	7-day intervals	14-day intervals
Arsenite of soda 80 per cent, pounds..........	4	8	12
Soft soap, pounds..........................	3	6	6
Paraffin, gallons..........................	1	2	2
Water, gallons.............................	400	400	400

In practice the soap and paraffin are frequently omitted, a simple arsenical solution apparently bringing satisfactory results.

For the destruction of lice the following mixture has been recommended. Caustic soda 1/4 pound, white arsenic 1/2 pound, sodium carbonate 1/2 pound, and water 30 gallons. The mixture is compounded in a similar manner as the ones in use for baths for tick eradication.

Sodium fluoride (NaF) has gained favor as an alimentary as well as a contact poison for chewing lice, and it has found a wide application in the delousing of poultry. It may be used as a dry powder or in solution. Used as a powder, a "pinch" of the chemical is sifted under the feathers of various regions of the body; if used as a dip, 1 ounce of the sodium fluoride and 1 ounce of laundry soap are to be dissolved in a gallon of water.

This disinfestant has the disadvantage of being irritating to mucous membranes and the skin, and therefore care should be taken that the dust is not too freely scattered about in the air.

Barium Carbonate ($BaCO_3$).—The powdered barium carbonate offers many advantages as a rat poison. It is tasteless, odorless, and it kills but slowly, causing the rats to die in their burrows. In the preparation of barium carbonate bait, the substance is mixed in foodstuffs in the proportion of one to four.

Phosphorus paste and strychnin are also used in baits for the destruction of rats and other rodents. They are not as readily taken by rats as the barium carbonate and have the disadvantage of marked toxicity for man and the domestic animals. Strychnin appears to be the most satisfactory poison in use for the destruction of such rodents as ground squirrels, gophers, etc.

Squills (Urginea maritima).—On the continent of Europe the use of squills as a rat poison is commonly approved as an effective dis-

infestant, and there it is a common ingredient of many commercial rat poisons. *Urginea maritima* is a perennial plant with a pear-shaped bulb varying from 6 to 12 inches in diameter and weighing as much as 5 or 6 pounds. The bulb is made up of fleshy scales. Scillitoxin, scillipicrine, scillin, scillain and the carbohydrate sinistrin constitute the toxic principles of the plant.

The poison bait is prepared by grinding the fresh bulbs in a meat grinder and by working the chopped material into a dough with sausage meat and flour. The mixture is baked with grease into pancakes which are then used as bait.

Formaldehyde is an excellent disinfectant, but with one exception practically without value as a disinfestant. The exception consists in its toxicity for the common house fly. Solutions of formaldehyde not only attract this insect, but constitute an effective alimentary poison for this species. A mixture of 1 part of formaldehyde solution (40 per cent) and 30 parts of milk diluted with equal parts of water and exposed in shallow vessels, will rid a given space of flies within a relatively brief period. This is particularly the case in the absence of other foodstuffs and water.

Contact Poisons.—Contact poisons are particularly applicable in the destruction of arthropods provided with piercing-sucking mouth parts. They are most apt to penetrate the body of infestants through avenues other than the digestive organs. However, they may also act as alimentary poisons or fumigants or be useful in disinfestation where chewing insects are concerned which cannot readily be destroyed by mixing stomach poisons with their food.

The contact poisons commonly enter through the spiracles or respiratory tubes and act either chemically or in a mechanical manner by plugging the breathing tubes. Certain substances such as soaps and other fat solvents have been shown to be able to penetrate the trachea by capillarity.

Evidence presented by Shafer indicates that the action of certain common contact poisons after absorption consists in rendering the tissues affected incapable of assimilating oxygen.

On the whole, the various contact poisons occupy a most prominent place among disinfestants used in livestock sanitary practice.

Nicotine ($C_{10}H_{14}N_2$).—The sulphate of nicotine is one of the most widely used disinfestants. It is most commonly sold in solutions containing 40 per cent by weight of nicotine and appearing on the market under various trade names.

Solutions of nicotine sulphate are in general use as dips for the

destruction of the mites causing mange and scabies of cattle and sheep and of cattle lice. The great toxicity of this contact poison demands care in its preparation, but it offers the advantage of being less bulky in handling and requiring less labor and equipment for the compounding of the dipping solution.

To be effective as a disinfestant, the dipping solution must contain not less than 0.05 per cent of nicotine. More concentrated solutions should be avoided, owing to the toxicity of the nicotine. In dipping practice in the United States the strength of the bath fluid is constantly controlled by a specially designed field test.

The addition of sulphur (16 pounds of the flowers of sulphur to 100 gallons of dip) is a common practice in this country, although it is not quite clear how the insoluble sulphur could add to the disinfesting powers of a nicotine solution of standard strength.

Oil.—Vegetable oils such as raw linseed or cottonseed oil, and animal oils such as fish oil, are very extensively used as delousing agents. They are quite valuable in the control of blood-sucking lice which are not affected by sodium fluoride. They are applied by means of a stiff brush or simply rubbed in by hand. After the oiling, the animals treated should not be exposed to the direct rays of the sun, as otherwise a dermatitis may be the result.

Crude Mineral Oils.—Petroleum and its derivatives are effective contact poisons useful in the eradication of ticks, mites and lice. Formerly a dip prepared by floating a layer of crude petroleum on the surface of the water in the vat was extensively used as a disinfestant in tick eradication, but it has now been largely displaced by the arsenical dips.

Crude oils which contain from 1¼ to 1½ per cent of sulphur and of which 40 per cent of the bulk boils at a temperature ranging between 200° and 300° C. are particularly effective against mites. If the recently dipped animals are kept quietly in a shady place, such oils can be safely used in undiluted form. They are useful in the extermination of poultry mites in houses.

Preference is usually given to the emulsified oil. A stock emulsion to be diluted to suitable strength may be prepared by boiling 1 pound of laundry soap in a gallon of soft water, to which 4 gallons of crude petroleum are added as soon as the soap has been completely dissolved.

Kerosene emulsion is a time-honored delousing agent and may be prepared as follows: Dissolve ¼ pound of hard soap in a gallon of soft water by boiling. When the solution is complete and still hot,

pour into it 2 gallons of kerosene and stir vigorously. Of the creamy emulsion thus formed, 1 part is added to from 10 to 15 parts of soft, warm water; the mixture should then be immediately applied as a spray or by means of a stiff brush. Old emulsions in which the kerosene has separated should be rejected.

Sulphur and Sulphides.—Sulphur and preparations containing this substance have long been reputed to be valuable as remedial agents in certain skin diseases, and particularly those caused by epizoa. Sulphur ointment is still a specific for human scabies.

In livestock sanitary practice sulphur combined with calcium or sodium is extensively used in the eradication of scabies and has proved to be an effective acaricide. This action has not been satisfactorily explained. Sulphide solutions apparently have a softening effect on the substances which help to make up the body surface, and it is by no means impossible that volatile sulphur compounds may enter the interior of the body.

As disinfestants in mite eradication the sodium and calcium sulphur compounds are used. The lime-sulphur combination finds the widest application in the control of scabies in sheep and cattle.

The sodium-lime dipping fluids may be prepared in accordance with a South African formula. Twenty pounds of flowers of sulphur are stirred into a creamy mixture with not more than 2½ gallons (imperial) of hot water. This being completed, 5 pounds of caustic soda are slowly mixed in by constant stirring. After about 40 minutes the resulting mixture is poured into 100 gallons of water for use in the vat.

Various sulphides are formed by the combination of the caustic soda and the sulphur. They are collectively designated as polysulphides. These may contain:

Sodium monosulphide (Na_2S).
Sodium disulphide (Na_2S_2).
Sodium trisulphide (Na_2S_3).
Sodium tetrasulphide (Na_2S_4).
Sodium pentasulphide (Na_2S_5).

The lime-sulphur combinations are analogous to the above. These combinations are prepared in varying proportions. The weighed quantities of lime and sulphur are boiled in relatively small quantities of water until all affinities between the component parts have been satisfied, and the resulting concentrated solution of polysulphides is then diluted to dipping strength.

The following combinations are most generally used in the United States:

For Sheep Dipping

Flowers of sulphur	24 pounds
Unslaked lime	8 pounds
or hydrated lime	11 pounds
Water	100 gallons

For Cattle

Flowers of sulphur	24 pounds
Unslaked lime	12 pounds
or hydrated lime	16 pounds
Water	100 gallons

Such dips must be used at temperatures of from 95° to 105° F., and the official control test should show them to contain not less than 1.5 per cent of "sulphide sulphur" for a sheep dip and not less than 2 per cent for a cattle dip.

The lime-sulphur dip in use in South Africa corresponds to the American formulas. It is prepared with the following ingredients:

Flowers of sulphur	25 pounds
Unslaked lime	15 pounds
or hydrated lime	20 pounds
Water	100 gallons (imperial)

Pyrethri flores, or pyrethrum powders, consist of the unexpanded flower heads of several species of chrysanthemum. As the product appears in the trade it ranges in color from yellow, yellowish brown or brownish yellow to a yellowish green, the better grades verging toward the brown and the more inferior ones toward the green.

These substances owe their insecticidal powers to a volatile oil very toxic to many insects. Pyrethrum rapidly deteriorates with age, and old preparations may be entirely useless. The powder is used to dust into the hair and feathers of infested animals. It is too costly for general use in livestock sanitary practice, but occasionally it may find use in the delousing of single animals and serve to relieve sheep from the sheep tick or ked.

Copper sulphate ($CuSO_4 5H_2O$) occurs as deep blue triclinic crystals soluble in 3.5 parts of water. In the form of the commercial "bluestone" it is used in the eradication of certain species of snails which serve as an intermediary host to "liver-flukes."

Fumigants.—Disinfestants in gaseous form are spoken of as fumigants. They can be used only in closed spaces, and as most of the structures which may have to be disinfested in livestock sanitary practice are not of a tight construction the use of fumigants is a rather restricted one. Fumigation, when used for disinfesting purposes in a suitable situation is, as a general rule, more effective than when applied for disinfection.

Hydrocyanic acid (HCN) is extremely toxic to all forms of animal life, including the eggs. It should be used by a trained personnel only. The gas is usually prepared from a cyanide in the space to be disinfested, but it may also be procured in liquefied form under pressure in steel containers.

The gas is colorless and slightly lighter than air. It is marked by a characteristic odor and it is not inflammable. It diffuses rapidly, but its penetrating power for closely packed materials is but slight.

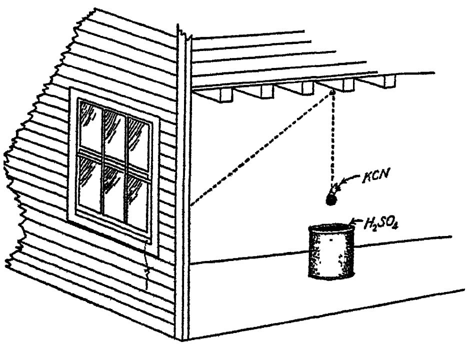

FIG. 67.—Method of disinfestation by means of hydrocyanic gas.

For practical purposes, hydrocyanic acid gas is prepared by the action of sulphuric acid upon sodium or potassium cyanide. The required amount of dilute sulphuric acid is placed in an earthenware container, and the cyanide contained in a cheesecloth bag is suspended above it by means of a string by which it can be lowered into the acid from without.

The quantities needed for every 100 cubic feet of space to be disinfested are the following: Water 3 fluid ounces, commercial sulphuric acid 1½ fluid ounces, sodium cyanide 1 ounce. If the liquefied gas is used, 1 pound of the latter will be sufficient to treat 1000 cubic feet of space into which the gas is admitted by means of metal pipes or rubber hose placed with due regard for the safety of the operators.

Calcium cyanide ($Ca(CN)_2$) which slowly yields hydrocyanic gas is used in the form of dust for the control of rodents. It is either placed in the burrows or is forced into them by means of a blower.

Sulphur Dioxide (SO_2).—This gas has already been described as a disinfectant and therefore the methods of preparation and of application will not require to be described again. Its effectiveness as a disinfestant exceeds that as a disinfectant.

The gas will promptly kill rats and mice and all the arthropods which may play a rôle as infestants. It is less active in the destruction of eggs. Sulphur dioxide as a disinfesting fumigant is applicable only to spaces enclosed in rather tight walls. It has been exceedingly useful in the deratting of ships, and it may also be of value in the case of well-constructed granaries, stables, etc.

In such places it can be used for the eradication of mosquitoes and flies. The latter are destroyed in 1 hour if 2 pounds of sulphur per each 1000 cubic feet of space are burned within a reasonably tight enclosure. The burning of 3 pounds of sulphur and an exposure of 6 hours in a similar space is required for the killing of rats and mice.

Lice are still more resistant, and their destruction is accomplished only by a 6-hour exposure to the dioxide formed by the combustion of 4 pounds of sulphur for every 1000 cubic feet of space.

Vigel and Chollet, of France, and Nöller, of Germany, simultaneously devèloped a method for the disinfestation of animals affected with mange or scabies by the use of sulphur dioxide. The method proved to be particularly applicable to horses suffering from mange. The animals, with the exception of the head, are enclosed in hermetically sealed gas cells to which the gas is admitted. The head and part of the neck are treated with acaricidal disinfestants. From 4 to 5 volume per cent of the gas are required for the treatment, and the exposure is prolonged for 1 hour.

Carbon bisulphid (CS_2) is used to a limited extent in livestock sanitary practice chiefly for the destruction of rats and other burrowing rodents. It is a volatile, malodorous, nearly colorless liquid, which rapidly changes to a gas when exposed to the air. This gas is 2.63 times heavier than air and is highly inflammable and explosive, a quality which must always be given consideration as a matter of safety and likewise because the use of this disinfestant may invalidate certain fire insurance policies.

The gas is toxic for arthropods as well as for rodents. For the destruction of the latter a ball of cotton waste or of a similar material is saturated with an ounce or more of the liquid and deeply inserted into the burrows, the opening of which must be closed with

puddled clay or soil. This method of disinfestation is most successful in the heavier, damp soils.

Blankets, grooming utensils and garments may be effectively deloused if placed in a tight container and exposed to the vapor of the carbon bisulphide, placed in a shallow vessel resting on the top of the material to be treated.

For the disinfestation of larger spaces, from 2 to 3 pounds of the liquid are required for every 1000 cubic feet of space. The exposure should be continued for not less than 24 hours, and optimum results are obtained if the prevailing temperature is not below 75° F.

Carbon bisulphide has been found to be a valuable internal fumigant for the purpose of ridding the stomachs of horses of the larvae of *Gastrophilus* species. For this purpose, it is administered in gelatin capsules, each containing 10 to 12 c.c. of the liquid.

Carbon tetrachloride (CCl_4) is only occasionally used as a disinfestant, but its killing power is less than that of the bisulphide. It is non-inflammable and hence may be useful in situations where the use of carbon bisulphide may be hazardous.

Carbon monoxide (CO) contained in the exhaust gases of gasoline motors and conveyed to the burrows of rats has been shown to be a very effective fumigant.

Repellents.—Substances which repel certain insects may, for a time, bring peace and comfort to animals, but they cannot be classed as disinfestants. Various essential oils, tar, crude carbolic acid and fatty oils are used for this purpose. As a rule, their effect is of short duration. A mixture commonly recommended for repellent purposes is composed of 1 part of crude carbolic acid, 50 parts of oil of tar and 100 parts of fish oil.

Flying insects may be repelled by the smoke smudge created by burning of damp straw, stable manure and similar substances.

BIOLOGIC CONTROL

The biologic control of infestants consists in exposing them to their natural enemies. In livestock sanitary practice, the principle of this method of control has been applied to only a very limited extent.

Rats have been exposed to bacteria having a more or less specific pathogenicity for these rodents in the attempt to bring about destructive epizootics in rat populations. Colon-typhoid intermediates have been most commonly used for this purpose. The results have

been mostly far from satisfactory. Most of the many alleged viruses have been found to be entirely harmless to the rodents and only a very few were proved to be pathogenic. A European virus of rather good repute is, by its promotors, recommended to be supplemented by an alimentary poison, because only a part of the rats are fully susceptible.

American preparations tested by the North Dakota Agricultural Experiment Station proved to be uniformly worthless, and the National Biologic Survey also regards them as quite inefficient and unsatisfactory.

PRACTICAL APPLICATION

In livestock sanitary practice the methods of disinfestation are generally applied to the infestants which either are themselves pathogenic or which play a part as mechanical or biologic vectors of certain diseases. In connection with the latter, systematic disinfestation is often imperative if animal husbandry is to be carried on in a profitable manner. In others the well-being and comfort of animals may be materially promoted by the abatement or eradication of the various pests which are factors of mere annoyance or which are actually parasitic.

As a rule, disinfestation applies to the infestant itself, but whenever the latter inhabits animals living in the wild state the host must be included in the process. The destruction of ground squirrels and other rodents infested by plague-carrying fleas may serve as an example.

A brief consideration of the methods of disinfestation employed in dealing with a number of infestants of livestock sanitary importance may illustrate the principles involved.

Rats are the hosts of trichina, plague-transmitting fleas, and the mechanical vectors of certain microbic diseases; as such they may have to be dealt with in the practice of environmental hygiene.

The solution of the rat problem is best approached by rat-proof construction, because these animals nearly always choose their habitat in inhabited places, where food and shelter are most available. To build the rats out is the most promising method of solving the problems associated with them. This may be designated as preventive disinfestation and should be made to include the proper rat-proof storage of foodstuffs, scrupulous cleanliness and the prompt and adequate disposal of all waste matter.

Active disinfestation consists of the use of such alimentary poisons

as barium carbonate and squills, systematic trapping and the application of fumigants such as sulphur dioxide, carbon bisulphide and gasoline, motor exhaust gases (carbon monoxide) to the burrows wherever this is possible. These measures are also of service in dealing with other burrowing rodents.

Lice.—Many of the disinfestants previously named are effective against lice. The latter must be destroyed on the body of their hosts. As the eggs of lice are more resistant it will commonly be necessary to repeat the disinfestation at some period after the hatching of the eggs and before the young lice can become sexually mature. About two weeks after the first treatment will ordinarily be a suitable time.

If only a few animals are to be deloused, hand treatment, consisting of the application of a disinfesting fluid by means of a brush or spray, will usually be sufficient. The liquid disinfestants are commonly chosen in the case of cattle, horses and swine, but in poultry and pet animals dusting powders may be preferable. If a considerable number of large farm animals are to be treated the practice of dipping must be resorted to.

For the hand treatment of horses, cattle and swine, raw linseed oil applied by means of a brush will be effective if the treatment is repeated at least once from 10 to 20 days after the first. Raw linseed oil is not only very suitable for application to individual animals, but is also quite economical, one pint often being enough for four or five cows.

Crude petroleum applied by hand or as a bath is effective in the delousing of swine. A mixture of equal parts of kerosene and lard or oil is equally useful. Spraying or brushing with kerosene emulsion readily destroys lice on all animals.

When dipping has to be resorted to, the arsenic, nicotine or kerosene emulsion dips can be chosen from.

Dusting powders are useful if for any reason the use of liquid disinfestants is contraindicated. Sodium fluoride is very effective in the eradication of biting lice, but cannot be depended on for sucking lice. Pyrethrum powders are indicated when delicate pet animals are to be deloused. For the larger animals this delousing agent may prove to be too expensive.

Fluoride of sodium is now in general use for the eradication of biting lice of poultry. A small quantity of a 50 per cent mercurial ointment is likewise effective when carefully rubbed under the feathers. This ointment may also be useful on other animals, but

cannot be recommended for cattle because of their marked susceptibility to mercury poisoning.

Fleas on dogs and other animals may be destroyed by the use of kerosene emulsion. In the case of long-haired, delicate parlor dogs and cats, pyrethrum powders are preferable.

Because fleas do not constantly inhabit their hosts and because they propagate themselves in kennels, blankets and other litter, such material must be treated separately. Cheap bedding is best destroyed by fire; the application of gasoline to the more valuable fabrics will also prove to be effective.

Mites.—The suppression of the communicable skin diseases of domestic animals constitutes, in many sections, one of the principal tasks of the livestock sanitarian. Like in other attempts at disinfestation, prevention and cure must be simultaneously accomplished. Preventive and curative medicine here occupy common ground. If the latter fails, the task of the former remains undone.

The most effective measures in dealing with the *Psoroptes, Chorioptes, Sarcoptes* and *Demodex* of cattle, sheep, horses and swine is the total submersion of the affected or exposed animals in acaricidal solutions.

The *Psoroptes* mites are the most readily destroyed by such solutions, among which the lime-sulphur compounds and nicotine baths are the ones most frequently employed.

Cattle to be dipped should be fed and watered from 2 to 4 hours before they enter the bath. The animals should not be heated or fatigued, and the time of dipping should be so chosen that the animals have ample time to become thoroughly dry before sunset.

The dipping fluid should be kept at standard strength. When lime-sulphur solutions are used they should be maintained at a temperature ranging between 95° and 105° F. Owing to the volatile character of nicotine, dips prepared with this substance should be kept at a somewhat lower temperature (95° to 100° F.) and this should never be permitted to rise to 110° F. An exposure of 2 minutes is sufficient in the case of nicotine dips; from 2 to 3 minutes are required when a lime-sulphur solution is used. Even a longer dipping period may be warranted in the case of animals covered with thick scabs and a heavy hair coat.

The dipping should be repeated in from 10 to 12 days inasmuch as the first treatment does not destroy the eggs of the mites. The eggs hatch within 10 days, and the young mites can be readily killed by the second bath.

In the dipping of sheep the same practice is followed. These animals should not be dipped within a period of 10 days after shearing in order to give wounds and abrasions time to heal. In very severe cases of scabies the period in the bath may be prolonged to 5 minutes.

The *Sarcoptes* mites of cattle, horses and swine are not so readily destroyed, and the older cases may require several treatments before disinfestation becomes complete. In cattle this usually requires four dippings in either nicotine or lime-sulphur solutions at intervals of from 6 to 10 days.

If crude petroleum is used for the purpose, one dipping frequently proves to be sufficient. Cattle, as well as other livestock, must be carefully handled after the petroleum bath and should not be exposed to bright sunshine or be permitted to chill or be injudiciously driven.

For the destruction of *Sarcoptes* mites on horses and swine, crude petroleum is probably the best material, if used with the caution recommended above. Oil dips are used cold or but slightly warmed during the colder seasons. In animals only recently exposed, or but slightly affected, one dipping will often prove to be sufficient. In more thoroughly infested animals the treatment should be repeated at intervals of from 6 to 10 days.

On the continent of Europe, horses affected with sarcoptic mange are successfully treated by the fumigant sulphur dioxide (anhydrous). The animals to be treated are thoroughly clipped and placed in a hermetically closed gas cell. The head is made to protrude through a special opening which is then closed by the adjustment of a suitable collarette fitted around the head and neck.

When the horse is thus secured, from 4 to 5 volume per cent of the gas is admitted from the steel cylinder in which the liquefied sulphur dioxide is contained. The temperature within should be from 80° to 86° F., and the exposure must be continued for 1 hour. The treatment is repeated after from 5 to 11 days. In old cases this may have to be done three or four times. Head and neck are treated with a suitable acaricide while the animal is still in the cell.

Demodex mites are difficult to destroy, and though they may be held in check by such dips as crude petroleum, it is preferable to dispose of marketable animals for immediate slaughter as the most economical solution of the problem.

Hand treatment by which the disinfestant solution is applied to the animal body by means of brushes or sprays does not usually prove to be effective in the case of the larger farm animals. In swine, crude

petroleum may thus be applied, and in rabbits affected with ear mange (*Psoroptes, Chorioptes*) and in fowls with scaly legs (*Cnemidocoptes*) no other treatment is possible. In the former a mixture of oil and from 10 to 20 per cent of gasoline is used, and in the latter a mixture of 2 parts of raw linseed oil and 1 part of kerosene is usually effective.

After the disinfestation of the animal body has been accomplished, the infested environment may require attention. Most mites will live in bedding and other litter from two to three weeks at least, and in some cases they were found to be alive two months after removal from the body of their hosts.

A contaminated environment, therefore, should either be avoided by clean animals for from two to three months or all litter be carefully removed and destroyed by fire. After this done a spraying with a crude carbolic acid solution should be applied.

In the control of the chicken mite (*Dermanyssus*) attention must be exclusively devoted to the environment, more especially the poultry house. Spraying with crude petroleum or a mixture of used crank case oil and kerosene (2:1) is an effective method of disinfestation.

Ticks.—In several regions of the world, ticks constitute a barrier to animal husbandry which must be removed before any degree of success can be attained. They are noxious as mere parasites, but the fact that they are the intermediary host and vectors of such pathogenic protozoan forms as *Spirochaeta, Babesia, Anaplasma, Piroplasma, Theileria* and *Gonderia* causes their eradication to constitute a livestock sanitary task of the first magnitude. This task was practically a hopeless one until it could be founded on a more or less accurate knowledge of the anatomy, natural history and life habits of the species which have an hygienic importance.

Ticks constitute a superfamily of the order Acarina. This superfamily, the Ixodoidea, comprises two families, the Argasidae and the Ixodidae, of which the latter have the greatest importance.

The Argasidae are divided into the genera *Argas* and *Ornithodorus.* The former are parasitic on domesticated birds and are represented by the species *Argas persicus* of America, *A. persicus* and *A. reflexus* of the old world, and *A. victoriensis* of Australia. The latter by the species *Ornithodorus* (*Otobius*) *megnini,* the spinose ear tick of America, the African *O. savignyi, O. moubata,* and the old world species, *O. tholozani* and *O. canestrinii.*

Argas miniatus of the southern United States hatch during warm

weather in from 10 to 15 days after the eggs have been laid. The larvae seek their hosts (fowls) at once and become engorged with blood in from 3 to 10 days. Once engorged, the young ticks leave the hosts and hide themselves in cracks and seams of the poultry house. In from 4 to 9 days they moult and acquire an additional pair of legs. Beginning with this stage, they seek their hosts and feed only during the night, going into hiding during the daytime. Subsequent to each of the first three meals they moult again, and with the conclusion of the last moult they appear as sexually mature males and females. After another meal of blood the females lay eggs, and unlike those of Ixodidae they may deposit as many as eight lots of eggs, each egg laying being followed by a new engorgement of blood. The adults of the species have a remarkable longevity and have been observed to remain alive without blood for as long as two years.

The spinose ear tick (*Ornithodorus megnini*) is parasitic on cattle, sheep and horses. It enters the auditory canal as a six-legged seed tick, attaches itself and sucks blood from the skin interior to the hair line. In that situation the tick becomes engorged, moults and changes to the eight-legged nymph. The ticks remain in the ear for several months, then they leave the host and conceal themselves in suitable places of the environment where they become adult and copulate. The eggs hatch and the larvae seek new hosts.

The Ixodidae constitute a much more important problem in livestock sanitation; in comparison with the Argasidae their life habits are more complex, and in addition they show a greater diversity in their biologic behavior.

All Ixodidae are fixed parasites and remain attached to their hosts for long periods. They have no food besides blood, and although they may be capable of remaining without food for long periods they are dependent on host contacts if they are not to starve and perish. The length of the period during which they can remain alive without food constitutes a detail of importance when certain disinfestation methods must be practiced.

In most of the Ixodidae, copulation takes place on the host animal. As soon as the fertilized female has engorged herself with blood she drops to the ground, hides herself and begins to oviposit. The number of eggs laid varies, but in most species several thousand are deposited. At the conclusion of egg laying, the female dies.

The larvae hatch after periods which vary with the different species. The larvae or "seed ticks" attach themselves to the grass or

other parts of the vegetation and there await the opportunity of making contact with a host animal.

From then on, the further development which concludes with the appearance of the adult ticks or imago varies in accordance with the species concerned. This variation is determined by whether or not the entire metamorphosis is completed on the original host. In some species a sojourn on more than one host animal is required to bring the life cycle to completion. Thus we have come to recognize one, two or three host ticks.

In the case of the single-host ticks, only one host connection is required from the larval to the adult stage. The larva, after finding its host, fills itself with blood and passes from the larval to the nymphal stage and from the latter to the adult stage without leaving the host animal.

The two-host ticks require a second host to complete their life cycle, because the engorged nymphs drop to the ground where a second moult takes place and where the sexually mature ticks take form. The latter must then seek their second and final host where they engorge themselves and again drop to the ground for ovipositing.

The three-host ticks need a third host to complete their progress from larva to imago. In these ticks the larva drops to the ground after engorging itself. On the ground it moults and becomes a nymph. The latter must now seek a second host upon which to gorge itself with blood. This accomplished, the nymph falls to the ground, moults again and appears as the imago. The latter now seeks a final host upon which it mates, gorges, and in the end drops to the ground where the eggs are laid.

The North American Texas fever tick, *Margaropus* (*Boophilus*) *annulatus,* the African blue tick (*Boophilus decoloratus*), the Australian cattle tick (*B. australis*), the South American ticks, *B. microplus* and *B. argentinus,* and the Asiatic tick, *B. calcaratus,* are all one-host ticks.

The time required for the completion of the life cycle of the Texas fever tick is greatly influenced by the prevailing temperature. During the warmer part of the year, egg laying begins in from 2 to 20 days and during colder weather in from 13 to 98 days after the female tick has dropped to the ground. She may deposit from a few hundred to more than 5000 eggs. The larvae hatch within a period as short as 19 days in the summer season, or the hatching may be delayed for as long as 200 days during colder weather.

The larva which finds a host immediately attaches itself and begins

to fill up on blood. It moults in from 5 to 12 days and becomes a nymph. The latter undergoes a second moult in from 5 to 11 days and then appears as the imago. After mating the female gorges herself with blood, and this process may require from 2 to 4 days. From 7 to 25 days may be required between the second moult and full engorgement. In rare cases the parasitic existence of the tick may be less than 20 days, but commonly it extends over 3 weeks or more. The longest sojourn of the tick on its host has been observed to be 66 days.

The time required for unattached larvae to perish by starvation varies in accordance with climate, weather and season. From 6 to 12 months will probably be required for the larvae to succumb to a lack of food.

The life cycle of the blue tick of South Africa is very similar to that of the American species. Its parasitic life, on the average, requires from 3 to 4 weeks. Unattached larvae may live from 6 to 7 months.

The hygienically more important two-host ticks include the red tick (*Rhipicephalus evertsi*) of South Africa and the *R. bursa* of southeastern Europe. The eggs of the African red tick hatch in about 30 days in summer. The larvae seek a host and after gorging moult into nymphs on the host. The nymphs also gorge themselves and drop to the ground after a parasitic existence of from 10 to 15 days. On the ground they moult into adults in 22 to 25 days.

The adults, after finding a host, gorge themselves and in from 6 to 9 days drop to the ground when the eggs are deposited. The larvae may live without food for 7 months and the adults from 12 to 14 months.

R. bursa has a similar life history.

The three-host ticks include many species of concern to the livestock sanitarian. The group includes the European castor bean tick, *Ixodes ricinus;* the Australian *I. holocyclus;* the South African *I. pilosus, Rhipicephalus capensis, R. simus, R. mitens, R. appendiculatus, Amblyomma hebraeum;* the North American *Dermacentor andersoni;* the English *Haemaphysalis cinnabarnia punctata,* and the more cosmopolitan *Rhipicephalus sanguineus.*

The life history of *Rhipicephalus appendiculatus* or brown tick is illustrative of other members of this genus. The female deposits from 3000 to 5700 eggs which, in summer time, require about 4 weeks for hatching and in winter time two or three times longer. The larvae which find a host remain there for from 3 to 7 days and drop

to the ground after they have gorged themselves with blood. In from 16 to 21 days they moult into nymphs, which again seek a host animal where they also remain from 3 to 7 days. After gorging themselves they drop to the ground, and after from 10 to 18 days they moult again and appear as the imago. The latter, upon finding a host animal, mates, and the female, after about 1 week of parasitic existence, drops to the ground where the eggs are deposited. The larvae may live without food for from 7 to 11 months, the nymphs from 6 to 7 months, and the adults for more than 2 years.

The bont tick (*Amblyomma hebraeum*) requires a longer time for the various phases of its life cycle. The females may deposit as many as 18,500 eggs, and these require from 8 to 10 weeks to hatch. The larvae which find a host remain there for from 4 to 20 days and moult in from 1 to 4 months after leaving their host. The nymphs are parasitic for from 4 to 20 days. When fully gorged they drop to the ground, moult after from 18 to 25 days into the adult forms. Under certain conditions this period may be materially prolonged.

The females become engorged in from 6 to 25 days. Engorgement being completed, they drop to the ground and remain there from 1 to 10 weeks before they begin to deposit their eggs. The larvae may remain alive without food for about 1 year, the nymphs for 6 to 8 months and the adults for nearly 2 years.

Dermacentor andersoni rarely completes its life cycle in less than 2 years and may require 3 or 4 years for the purpose. The adult ticks find their hosts in the spring. They mate and the female gorges herself in about 10 days and drops to the ground. There she begins to lay her 2000 to 7000 eggs in from 6 to 84 days, the process itself requiring from 15 to 40 days. The eggs hatch in from 2 to 8 weeks. Larvae which find a host become engorged in from 2 to 8 days, drop off and in a period of from 8 to 26 days or even longer, moult into nymphs. The latter again seek a host, gorge and drop off in from 4 to 10 days. They moult on the ground in from 12 to 170 days to appear as imagoes. Larvae may live from 30 to 120 days without food, nymphs for over 300 days and adults for more than 1 year.

Disinfestation methods applicable to the tick problem vary in character; some are largely palliative and others aim at complete eradication. The purpose of the latter is to kill the ticks present on the host animal and to starve them while they are on the ground. It is obvious that, in regions where ticks constitute a major livestock sanitary problem, the radical measures are always preferred. They are the most effective and in the end the most economical.

Among the palliative measures, hand picking and the burning of pasture grass may be mentioned. The former must be regarded as a makeshift method which can be applied only to single animals or small herds and where the more radical measures cannot be resorted to. The burning of pasture grasses toward the latter part of winter or early in the spring will, no doubt, reduce the number of ticks present, but the ones on the ground will escape destruction. The tick plague will be held somewhat in abeyance by this method, but it has no place in any scheme of thorough disinfestation.

Pasture husbandry in which artificial pasture lands enter into the plan of crop rotation in which the land is tilled from time to time has a pronounced effect on tick infestation. Changing a natural grazing ground to artificial pasture or meadows will aid materially in the process of tick eradication. Tick eggs deposited on clover or alfalfa land will not hatch in the proportion normal for eggs laid on virgin grazing grounds. The method cannot be classified as a radical one, but is a useful one in many sections.

The application by hand of disinfestant solutions or by means of sprays may be indicated where only a few animals or herds have to be considered. Hand treatment also must be resorted to when ticks are to be destroyed on parts of the animal body where the dipping fluid cannot reach them or when, like in the fowl tick, disinfestation of the environment is the method of choice. In the case of the latter, the poultry house is sprayed with crude petroleum or crude carbolic acid mixtures. To be effective, two or three treatments from 20 to 30 days apart are recommended.

Hand treatment must also be applied in the case of the spinose ear tick. A mixture of 2 parts of pine tar and 1 part of cottonseed oil has been found to be effective, when properly introduced into the animals' ears.

Spraying and hand dressing for the eradication of disease-transmitting ticks has not developed into a general practice inasmuch as other methods of disinfestation have proved to be more dependable.

The destruction of ticks by a bath in a disinfestant solution, or "dipping" as this method is most widely known, is indispensable wherever numerous animals have to be freed from ticks and where farms or even larger areas are to be cleaned in a durable manner. The animals are passed through suitable vats or tanks, built in the ground. The solutions to be used have already been mentioned in a previous section.

All animals apt to serve as hosts must, as a matter of course, be

included in the process. The stock should be thoroughly rested before the operations begin. They should have been fed an hour or two before, and it is important that they should not be thirsty when they enter the bath. A thirsty animal may be tempted to drink of the poisonous dipping solution with fatal consequences.

Dipping operations should begin early in the morning or even before sunrise during hot weather. During the colder seasons, dipping operations should be suspended in time to permit the animals to become dry before sunset. After the dip the animals should be quietly herded and not be rapidly driven. If petroleum is used as a dip they should be kept in a place sheltered from the hot rays of the sun and not be moved for some hours.

In tick eradication the dipping is to be repeated at intervals determined by the life history of the tick species involved, and it is considered to be a good practice to accustom the animals to the dipping fluid by using weaker solutions for the first dippings.

The object of systematic dipping is to destroy the ticks on the animals before they become adult and drop to the ground. The animals serve, thus, as the gatherers, and the parasites are destroyed before they can propagate themselves.

The intervals between dippings are the longest for the one-host ticks. In the case of the American *Margaropus annulatus,* complete eradication can be secured if between March and November the animals are dipped every two weeks. The blue tick of South Africa, completing its life cycle in 3 to 4 weeks, requires a dipping every third week for its destruction.

The two-host ticks, such as *Rhipicephalus evertsi,* or red tick, necessitate more frequent dippings. In order to accomplish their eradication it would be necessary to dip at least every eighth day.

A still shorter dipping interval is necessary for the three-host ticks, such as the South African brown ticks (*Rhipicephalus appendiculatus, R. capensis, R. simus, R. sanguineus* and the bont tick, *Amblyomma hebraeum*). A dipping every three or four days continued for a year would be the most effective method of eradicating these species. The intervals between dipping should not exceed the period during which ticks remain attached to their hosts.

Disinfestation by starvation is based upon the fact that all ticks are dependent upon the blood of some host animal for their existence. It is the only food the ticks can utilize, and if this fails then they must perish. If, thus, a given tick-infested area is kept unoccupied by host animals for a time beyond which ticks can no longer live,

they perish, and the land can again be restocked with tick-free (dipped) animals with safety.

The time after which ticks in a pasture die after the removal of suitable host animals varies, the principal factors being climate and weather. The United States Bureau of Animal Industry carefully studied these factors in their relation to the longevity of the Texas fever tick and published tables for the guidance of farmers and sanitary officials engaged in tick eradication. The following tables are taken from Farmers' Bulletin 1057.

TIME REQUIRED TO FREE PASTURES FROM TICKS BY STARVATION

Based on data obtained at Dallas, Texas, and Auburn, Alabama

Date of removal of all animals from pasture	Date when pasture will be free from ticks	Date of removal of all animals from pasture	Date when pasture will be free from ticks
July 1	Mar. 1	December 15 to March 15, inclusive	Sept. 1
August 1	May 1	April 1	Sept. 15
September 1	July 1	April 15	Oct. 15
October 1 to November 1, inclusive	Aug. 1	May 1 to June 15, inclusive	Nov. 1
December 1	Aug. 15		

Based on data obtained at Knoxville, Tenn.

January 1	Aug. 1	June 15	May 1
February 1 to March 15	Nov. 15	July 1	June 15
April 1 to 15	Jan. 1	July 15	July 1
May 1	Jan. 15	August 1 to 15	July 15
May 15 to June 1	Feb. 15	September 1 to October 1	Sept. 15

It was also found to be possible to free cattle from ticks by placing them on a series of non-infested fields. This procedure is based on the fact that the female tick must drop from its host before eggs can be deposited. Twenty days were found to be the shortest period for the appearance of larvae after the adult females dropped to the ground. Thus, reinfestation during the warmer part of the year will not take place until after the lapse of the 20-day period. As the time required for all the adult ticks to drop to the ground, after

the cattle were placed on clean land, also varies, the following data were established by the investigators of the United States Bureau of Animal Industry (Farmers' Bulletin 1057).

TIME REQUIRED FOR ALL TICKS TO DROP FROM CATTLE PLACED IN TICK-FREE LAND

When ticky cattle are placed on tick-free land during	All ticks will have dropped in	When ticky cattle are placed on tick-free land during	All ticks will have dropped in
August	Six weeks	March	Seven weeks
September	Six weeks	April	Six weeks
October	Eight weeks	May	Six weeks
November	Nine weeks	June	Six weeks
January	Ten weeks	July	Five weeks
February	Seven weeks		

The scheme of rotation proposed by the United States Bureau of Animal Industry is as follows for the southern half of the tick area: Beginning at any time of the year from March to September the cattle are removed to a tick-free field and left there for not more than 20 days. At the termination of this period the animals are removed to a second tick-free area for 20 days, and if at the end of that time any ticks remain on the animals the latter are placed on a third tick-free lot for a similar period. In such a case 60 days will have elapsed, a period sufficient for the time of the year indicated for all ticks to have left the animals.

From October to February the time needed for the appearance of the larvae is considerably longer than that required for all ticks to have dropped to the ground. Thus the animals could be left in the same field for the required period. These periods were also ascertained by the United States Bureau of Animal Industry, and quoting from Farmers' Bulletin 1057 they are as follows: (See p. 318.)

The disinfestation of land thus can be accomplished either by exclusion of all host animals until the ticks have starved, or by dipping the infested animals at regular intervals in accordance with the life history of the ticks involved, so as to prevent engorged females from reaching the ground for egg laying.

Legal measures establishing a quarantine of the tick-infested areas have been helpful not only in preventing an extension of tick territory, but also in furnishing a base line from which tick eradication

Date on which Seed Ticks will Appear after Ticky Cattle Have Been Placed on Tick-free Land

Based on data obtained at Baton Rouge, La., Auburn, Ala., and Dallas, Tex.

Date cattle placed on tick-free pasture	Date seed ticks will appear
January 1 to February 4, inclusive	April 24
March 3	May 3
April 15	May 20
May 1	June 5
June 5	June 25
July 1	July 25
August 5	Aug. 30
September 1	Oct. 7
October 1	Feb. 25
November 1 to December 15, inclusive	Mar. 3
Based on data obtained at Knoxville, Tenn.	
January 11 to March 4, inclusive	May 29
April 1	June 3
May 15	June 20
June 12	July 19
July 3	Aug. 2
August 6	Sept. 6
September 4	April 14
October 2	May 10

could logically proceed. Both the United States and the Argentine Republic have established boundaries separating tick-free and tick-infested territory which cannot be crossed by tick-bearing livestock. In this country the measure was first inaugurated in 1892, and three years later the quarantine line was extended from coast to coast. A campaign for complete eradication was begun in 1906.

Flies.—Various diptera have a livestock sanitary importance, either as the cause of annoyance of animals or as the mechanical or biologic carriers of pathogenic microbes or of macro-parasites. Some of them suck the animals' blood; others do not. Some are parasitic at some phase of their life cycle, and others infest the animal body when parts become attractive for egg laying and as a suitable medium for the larvae to develop in.

With a view to their hygienic importance they may be divided in the following groups: (1) non-blood-sucking flies; (2) blood-sucking flies; (3) blow flies; (4) bot and warble flies.

The best-known and most widely distributed representative of the non-blood-sucking flies is the common house fly (*Musca domestica*). This, as well as allied species, are scatophilic in their habits and hence not only are potential vehicles of pathogenic microbes, but also serve as the temporary host of certain cestodes of poultry. This fly breeds especially in the excreta of animals and various types of rubbish. Horse manure and other forms of stable filth are particularly apt to serve it in its propagation.

The adequate and prompt removal and disposal of stable wastes and other rubbish is the most effective means of disinfestation. The larvae in such materials may be destroyed by the use of hypochlorite of lime, but inasmuch as a considerable quantity of the compound (1 part to 8 parts of horse manure is required), its use on a large scale is not economical and is applicable only in restricted cases. Under similar circumstances the use of iron sulphate is more economical. It may be used in solution (2 pounds in a gallon of water per horse per day).

The adult flies may be kept out of stables which are darkened or properly screened. They may be caught in large numbers in suitable traps or poisoned by formaldehyde solutions. Electrified screens on which the flies are killed by the current have also been introduced as the means of disinfestation.

The blood-sucking flies include many species, of which the following are representative of the ones most important from a livestock sanitary viewpoint.

For practical reasons the mosquitoes or Culicidae may be included in this group. Though often seriously annoying to livestock these diptera are not as important in this connection as they are in their public-health relations. Several species are the vectors of the microbic causes of malaria and yellow fever in man as well as those of filariasis. In animals also they have been identified as the vehicle of filariae.

Most of the mosquitoes deposit their eggs upon the surface of water in which the larval stage of the life cycle is passed. It is not improbable that other moist places covered by vegetation serve also for several species as a medium in which they pass through their transformations.

Repellents may be used in abating the mosquito plague, and the adult insects in stables may be destroyed by fumigants. More effective

is the draining of breeding grounds and the application of kerosene on bodies of water which cannot be drained. The covering of water barrels and the elimination of sundry open containers in which rain water may accumulate are further aids in abating mosquito pests.

Simuliidae, black flies, or buffalo gnats have been responsible for losses among the domestic animals. They are apt to attack in overwhelming numbers and deposit with their bites a toxic substance. The notorious Columbacz gnat of the Danube countries, and other sections of Europe, is annually responsible for heavy losses. The flies deposit their eggs on the edges of rapidly flowing water in which the larvae develop. The latter attach themselves to rocks and other objects where they pupate. The imago issues from the pupal covering under water, rapidly rises to the surface and immediately takes flight.

Various repellents have been resorted to with generally indifferent success. The application of grease or oils is perhaps the best repellent measure. The elimination of rapidly flowing rills or brooks by impounding dams has been recommended, but no radically efficacious plan to cope with this plague can as yet be proposed.

Tabanidae, horse flies, gad flies, are among the largest of all flies and are capable of inflicting formidable bites not infrequently followed by exudation of blood. The bites are painful and animals may be terrorized by the presence of these flies. Even though bites in themselves are not very injurious, consideration must be given to the fact that the flies may serve as vectors for various pathogenic microbes. They appear to play a dominant part in the transmission of some of the trypanosomoses and must be reckoned with in the preventive measures directed against these diseases.

The female *Tabanus* seeks for egg-laying purposes moist or marshy ground where the eggs are deposited on various plants. The larval state is passed either in the water or on its edge in the soil, in decaying stumps, etc. When the larva is fully developed it buries itself and pupates. In some species the life cycle is a prolonged one.

In combating the onslaught of Tabanidae various repellents have been used. They are of questionable value although for a short time animals may thus be protected against bites. These flies do not remove themselves very far from their favorite localities, such as moist boggy areas covered with brush. These haunts should be avoided by livestock. The drainage and subsequent tillage of such places are perhaps the most effective preventive measures.

Stomoxys calcitrans or stable fly is widely distributed in all

regions of the earth. Not only does it become very troublesome to animals, but it has been shown to act as vector for certain trypanosomes and spirochetes as well as the carrier of such parasites as *Filaria* and *Habronema*. It plays a part in the transmission of swamp-fever of horses.

The female stable fly deposits her eggs in stable manure and decaying vegetable matter. After an incubation of from 2 to 3 days the larvae make their appearance. The latter usually pupate in from 2 to 3 weeks, but under unfavorable conditions this may be delayed to 78 days. As in the case of the house fly the propagation of *Stomoxys* may be prevented by the prompt removal of stable manure and other litter.

Flies belonging to the genus *Glossina* inhabit the African continent. Its most formidable representative, the notorious tsetse fly, is best known as the vector of trypanosomes and particularly of the one which causes ngana. The tsetse flies are all viviparous. The female deposits a single larva at a time, which immediately burrows into the ground and pupates. The duration of the pupal stage ranges between 17 and 72 days. All *Glossina* are more or less attached to definite localities known as fly belts, the nature of which varies with the species. The adult flies are inveterate blood suckers. Some species attack animals from about 9 A.M. to 4 P.M. (*G. palpalis*), whereas others are active only between 7 and 10 A.M. and 3 and 6 P.M. During warm nights livestock may not be exempt from fly attacks.

Owing to the nature of their range the eradication of the Glossinae is exceedingly difficult. In the case of *G. palpalis* the removal of large areas of bush vegetation has had favorable results; on other species, this method failed to make an impression.

The conversion of wild areas into agricultural lands has been recommended, but the value of the method is not generally supported. The destruction of brush by fire has also found application. In certain areas this appears to have at least diminished the pest, whereas in others the results were questionable.

Livestock may be kept away from fly areas or be protected by blankets, etc. Moving animals by night and giving them protection by day has been employed by travelers and trekkers. Smudges about the camps have also been used as repellent measures. On the whole, it does not appear that any method of disinfestation or protection has given satisfying results.

Melophagus ovinus, a wingless fly widely known as the sheep tick or ked, is a blood-sucking parasite of sheep, capable of damaging and

irritating the host animal as well as reducing the value of the fleece by soiling it with excreta and pupal cases. This insect is viviparous, the eggs being retained in a uterus, until in the course of about 1 week they have developed into larvae or pupae. The latter are deposited in the fleece to which they are attached. The young keds emerge from the pupae in from 19 to 24 days and become sexually mature 3 or 4 days later.

Sheep may be freed from keds by dipping. Most of the dipping fluids designed against scab mites destroy the adult parasites. The pupae, however, are not so readily destroyed, hence the need of repeating the dipping in from 24 to 28 days. Enclosures used for infested sheep should be thoroughly cleaned and all rubbish burned. As an additional measure such enclosures should not be used for clean sheep for a period of not less than 60 days.

Blow flies or maggot flies deposit their eggs in decaying animal matter such as the carcasses of domesticated or wild animals, the soiled, soggy fleeces of sheep and filthy, neglected wounds. The larvae or maggots hatch rapidly, in some instances within 1 hour. They mature in 5 or 6 days (*Chrysomyia*) and pupate. The pupal stage lasts from 9 to 12 days, a life cycle under favorable conditions being completed in three days. All species of *Sarcophaga* are larviparous. The screw-worm fly (*Chrysomyia*), in particular, is a noxious pest. Its maggots are capable of infesting wounds with fatal results (recently dehorned cattle) and are apt to destroy new-born calves on the range.

In the sheep-raising districts of Australia, New Zealand, South Africa and the southwestern United States, blow flies are known as sheep maggot flies, and there they often present a major problem. They deposit their eggs on the soiled, moist fleece, where the maggots, developing in large numbers, become fatally destructive.

The species involved are: *Chrysomya macellaria, C. albiceps, Calliphora augur, C. vomitoria, C. erythrocephala, C. stygia, Microcalliphora varipes, Lucilia caesar, L. sericata, Phormia regina, Sarcophaga carnaria, S. texana, S. robusta, S. tuberosa* and others.

Among the methods of control the prompt disposal of carcasses is the most important, and this should include as far as possible the destruction of dead, wild animals. Poisoning the maggots by applying arsenicals to the slashed carcasses has been recommended, and the practice has proved to be a useful one if carcasses cannot be readily destroyed. A solution of ½ pound of sodium arsenite in 5 gallons of water is sprinkled over the slashed carcass. By the use of traps, baited with decayed meat, the flies may be numerically reduced.

Various measures of preventing blow-fly damage to sheep are resorted to, particularly in Australia. The methods vary and include what is called "crutching," dipping, "jetting," and "swabbing."

"Crutching" consists of shearing away the fleece of the breech where soiling is most apt to occur. The entire area exposed to soiling by urine and feces or the afterbirth and lochia after lambing should be sheared close. This area should be extended well above the tail and be made to include the folds of the skin on either side. The method brings good results and especially so if applied shortly before parturition.

Dipping in arsenical baths brings only temporary relief, and the danger of poisoning in badly blown animals must be reckoned with.

"Jetting" is a practice originating in Queensland; it consists of drenching the parts involved with an arsenical solution (2 to 10 pounds of arsenic to 100 gallons of water). The solution is forced into the fleece by means of a single jet applied at high pressure. The method is most effective after the sheep have acquired a 2 or 3 months' growth of wool. The sheep are passed through a chute or race, and with adequate equipment and preparation a sheep may be properly "jetted" in 6 seconds. The results are not always satisfactory, but in many instances the animals have been sufficiently protected for a period of 2 months.

"Swabbing" differs from "jetting" only in the method of application of the disinfestant solution. It is applied by means of a small swab of rags tied to a stick.

The larvae of bot flies and warble flies are parasitic to many animal species, including sheep, cattle and horses. The flies are non-blood-sucking, but they seek the host species in order to deposit their eggs on the body surface. During the period of ovipositing they are the cause of great annoyance to the animals, which often become frantic on their approach. The disturbance thus produced greatly interferes with the quiet, peaceful existence upon which the yields of animal husbandry are in a great measure dependent. The flies having a livestock sanitary importance belong to three genera.

Oestrus ovis or sheep nose fly, bot fly, or grub fly is a very common pest. During the earlier months of summer, and frequently later, the adult female, apparently larviparous, deposits its larvae on the moist margins of the sheep's nostrils, during the hotter part of the day. The larva or grub works its way into the nasal passages and to the cavities of the head. There they develop. Certain data indicate that they may remain there for more than a year, although more commonly

the larval stage is estimated to last for 10 months. As many as 80 grubs have been found in one head, but the usual number ranges between 1 and 10. During the following spring or summer, the larvae leave the head and drop to the ground. They burrow into its superficial layers and there pupate. The pupal phase endures for from 40 to 60 days, depending on prevailing temperatures, and at its conclusion the adult fly makes its appearance.

Most control measures directed against this pest are more palliative than radical. The capture of the flies attached to fences or vegetation during cool mornings and evenings has been proposed. Avoiding wooded areas of pasture lands during the season and hours of ovipositing has also been recommended.

More effective, although by no means completely so, is the application to the nose parts of the animals of repellent mixtures of which pine tar is the basic ingredient. Equal parts of tar and grease or fish oil are most commonly used for this purpose. As this requires daily, individual handling of the animals, the method is scarcely applicable to large bands, so that a makeshift method is often used. It consists of smearing a thick tarry mixture on the inside of a V-shaped trough which supplies the animals with salt in the hope that in this manner a sufficient quantity of the repellent may become deposited on the nose and upper lip of the sheep. A more radical means of disinfestation has thus far not become available.

Hypoderma lineata and *H. bovis* or ox warble flies are widely distributed species, the adult of which, during the periods of ovipositing, become extremely annoying to cattle at pasture. The damage caused by the larvae is responsible for a serious depreciation of cattle hides.

The adult flies are abroad from April to September, with variations depending on the species and climatic conditions. Egg laying takes place in shade or sunshine and continues from 10 A.M. to 8 P.M. The eggs are usually attached to the hair of the legs. The larvae hatch in from 3 to 4 days and immediately burrow into the skin. After migratory movements between muscles and viscera for 7 to 8 months, the larvae reach the subcutaneous tissues of the back and loins, where they encyst themselves. A small aperture is made through the skin for breathing purposes. The further development during the encysted position requires from 35 to 90 days, after which the warble, by enlarging the opening in the skin, makes its exit and falls to the ground to pupate. The pupal stage lasts from 18 to 77 days, in accordance with the species. The warbles can be readily detected in their encysted

position during the latter part of winter and the earlier part of spring.

For the control of the ox warble fly, various repellents have been used, but on the whole, very little has been accomplished by this method. The housing of cattle during the daytime is much more effective, although only certain classes of cattle can be protected by such a measure.

The only radical method for the control of this fly consists of the destruction of the larvae as soon as they can be readily detected in the back of the host. They may either be squeezed out or be grasped by means of a suitable pair of forceps. The warbles removed in this manner must be carefully collected to be destroyed by burning. In order to avoid anaphylactic reactions, care must be taken not to crush the grubs during the process of extraction. The cattle should be examined at intervals, not to exceed 30 days, and all warbles which present themselves should be removed in the manner indicated.

Consistently carried out over large areas, this measure will certainly result in complete eradication, or at least in materially abating this pest.

Gastrophilus intestinalis, G. hemorrhoidalis, G. nasalis, the horse bot flies, are not only a source of annoyance to horse stock, but their larvae, firmly attached to the walls of the stomach and other parts of the alimentary canal, are not so rarely the cause of damage to these parts as may be supposed.

The adults of *G. intestinalis,* or common bot fly, make their appearance early in summer and persist until frost. They are short lived and take no food. The female fly deposits its eggs on the hairs of the legs, shoulders and abdomen of the horse, fastening them by means of a glue-like substance. The animals' scratching or nibbling themselves, or one another, conveys the eggs to the mouth, where they hatch almost at once. The larvae, thus set free, pass to the stomach, where they attach themselves and remain for 9 to 12 months. At the termination of this period they pass out of the body with the feces and fall to the ground where they pupate. The pupal stage lasts from 30 to 40 days, at the termination of which the fly issues and rapidly proceeds to propagate its kind in the manner described.

The life history of *G. nasalis,* also known as chin fly, is very similar to that of the common bot fly, with this difference; however, that it attaches its eggs to the hairs under the jaws and throat. How the eggs or larvae are conveyed to the stomach is not precisely known.

G. hemorroidalis, or nose bot fly, deposits and attaches its eggs to

the skin and hairs of the lips. Its ovipositing causes much annoyance and excitement to the horses involved. How the larvae emerge from the eggs and gain the stomach is not known, but it is assumed that they are swallowed with food and water. They attach themselves to the wall of the stomach, but unlike the other species of bots, they also attach themselves to the walls of the rectum and anal canal shortly before they make their exit from the body.

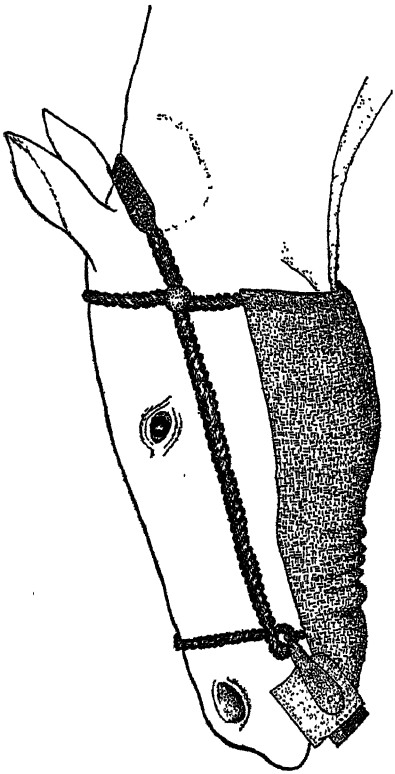

FIG. 68.—Protection against ovipositing bot flies. (After Dove.)

Both palliative and radical measures against bot infestation are applied. Among the former a repellent, consisting of equal parts of pine tar and lard, applied to the parts to which the flies are most liable to attach their eggs, has met with a degree of favor. Its effect rarely lasts for more than 4 days and hence the application should be renewed at the termination of this period.

Horses at work or at pasture may be protected with mechanical devices of various types. A strip of leather covering the lips of the horse and suspended from the bridle was most satisfactory in the control of the nose fly in the experience of Dove, who also combined it with a covering of canvas suspended beneath the jaw and neck to protect against the ovipositing of *G. nasalis*. For the destruction of the larvae in the eggs attached to the hair, Dove found that washes of a 2 per cent solution of phenol were the most effective.

Radical disinfestation may be undertaken late in the fall or early winter when the bots are all attached to the walls of the stomach. Carbon disulphide is used for the purpose. Horses to be treated are fastened for from 12 to 18 hours, and during the evening preceding the treatment a purge is administered. On the following morning the

carbon disulphide is given. Three doses of from 10 to 12 c.c. for adult horses are given 1 hour apart. The fluid is administered in gelatin capsules. Yearling colts receive half the amount required for adult horses. Especially if the treatment is applied late in winter, the feces containing the detached but still alive bots should be gathered and burned, and it may not be amiss to apply this procedure after the earlier treatment also.

Snails.—Snail species of the genus *Limnae,* varying for different parts of the world, serve as the intermediate hosts for the trematodes responsible for distomatosis. These snails, inhabiting marshy land, shallow accumulations of surface water and "pot holes," constitute the principal factor in making liver fluke disease, or liver rot, an enzootic disease.

The successful prevention of the disease depends on the elimination of the snails from a given environment or pasture land. As the snails are aquatic animals the drainage of the land becomes an efficient means of disinfestation. This cannot always be practiced in the newer countries where an exclusive animal husbandry has not yet been displaced by a more variegated type of agriculture. In such areas the use of disinfestants capable of destroying the snails is plainly indicated.

It was shown by Chandler that bluestone (copper sulphate) even in very minute quantities is highly toxic to the snails, and that it could be utilized in an economic manner. Experience indicated that a dilution of 1 part of bluestone to 1,000,000 or 2,000,000 parts of water is sufficient to destroy the snails, provided that the water does not contain too great an amount of organic material and that it is relatively free of algae and other aquatic plants.

The method is successfully applied to the infested grazing grounds of Australia. Preparatory to the application of the blue-stone, boggy land is ditched and the shallow pools of surface water freed from weeds.

The bluestone may be applied in various ways. Four or five pounds of it may be placed in a small bag which is then fastened to a pole. The operator walks along the ditch or brook, moving the bag in the water. Or the copper salt may be used dry on boggy land. Clunies Ross recommended the broadcasting of a mixture of finely ground bluestone and sand in the proportion of 1 : 4 at the rate of 30 pounds of the copper compound per acre. The copper treatment may be applied at any time of the year, but in Australia preference is given to its use before the end of December (June in the northern

hemisphere). A second treatment, six months later, is recommended. The best results are attainable if the copper sulphate is distributed just before a rainfall or while a light rain is falling.

Dipping Equipment.—The equipment required for the dipping of livestock varies with the kind of animals to be treated, as well as with their numbers. Where only a few sheep have to be treated in an emergency, almost any container in which an animal can be sufficiently submerged will be made to answer the purpose, and wash tubs, water troughs and the like may be used. Bags made of heavy canvas are occasionally used for the purpose.

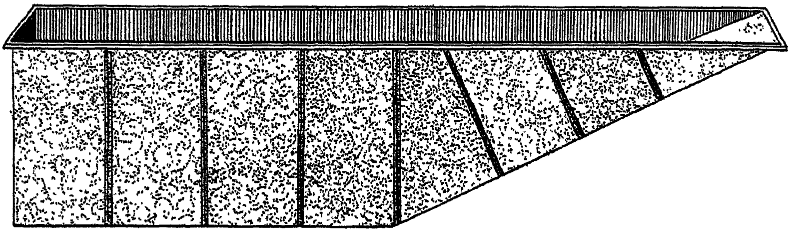

Fig. 69.—A portable dipping vat for small animals. (After Imes.)

When several animals have to be periodically treated and especially in the case of horses and cattle, a more elaborate equipment will be necessary.

The type of dipping vat most commonly used for the treatment of a considerable number of animals is known as the "plunge vat" or "swimming vat." These structures are built in the ground and may be constructed of lumber, galvanized iron or concrete. The latter is the more durable and will serve best wherever dipping is a more or less perennial practice. Such vats vary in size in accordance with the kind of animals to be treated and with their number.

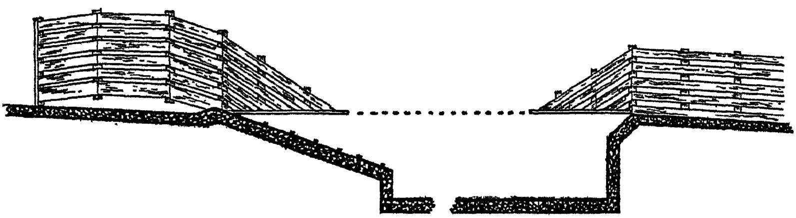

Fig. 70.—Section of large concrete dipping tank. (After Imes.)

Vats to be used for sheep range from 30 to 100 feet in length. The more animals there are to be handled the longer should the vat

be. Such a vat should have a depth of 5 feet with a width of 2 feet at the top and of 8 inches at the bottom. The end of the vat where the animals enter the bath should constitute a declivity of 45 degrees, of which the lower part must reach at least 6 inches below the surface

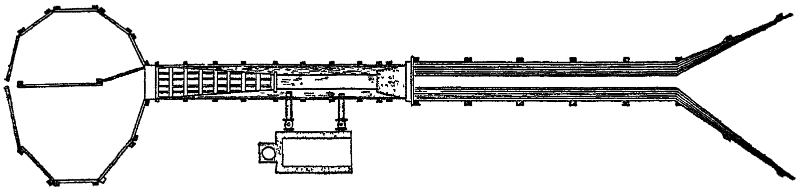

FIG. 71.—Top view of large wooden dipping tank. (After Imes.)

of the dipping fluid. At the end where the sheep emerge from the bath the bottom of the vat slopes gently upward and must be provided with cleats to give the animals a secure footing. For the larger vats this runway should be about 16 feet in length, and for the smaller ones from 8 to 10 feet.

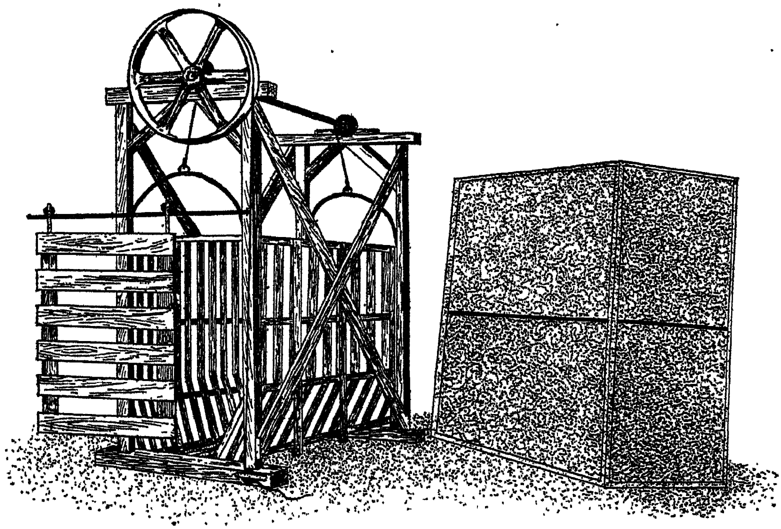

FIG. 72.—Hoisting dipping vat. (After Newberry.)

Swimming vats used for cattle must be of more ample proportions. In accordance with the number of cattle to be dipped, the length ranges between 40 and 120 feet. A vat for cattle has a depth of 8 feet, about 6½ feet of which is occupied by the bath fluid. The width at the top is 3½ feet and at the bottom from 18 to 20 inches. The

slide arrangement for entrance as well as the runway for exit are similar to the ones used in the smaller vats.

Dipping vats for the treatment of swine are built in the same form as those used for sheep. They are from 20 to 40 feet in length and have a depth of 4½ feet; the width on top is 2 feet and at the bottom from 8 to 12 inches.

For a relatively small number of animals a "cage vat" or "hoisting vat" is a very convenient type of dipping equipment. Such a vat also built in the ground has a length of 8 feet 10 inches, a width of 3 feet and a depth of 8 feet. The animals to be dipped are forced into a cage which is suspended above the vat and which can be raised or lowered by means of a suitable tackle or a large pulley in the manner of a common elevator or lift.

This type of equipment permits a more gentle handling of the animals and is particularly useful for the dipping of work horses, dairy cattle and the like. Power used for the operation of the hoist may be provided by a horse, a team of horses, or a tractor.

The dipping fluid may be heated by pipes connected with a steam boiler and placed along the floor of the vat, or by an open heating tank placed alongside the vat and communicating with it by means of an intake and a return pipe (6 inches).

The topography of the land permitting, all tanks should be provided with a drain; if this is not possible, pumping facilities for the emptying of the vat should be made available. Suitable chutes of approach and a dripping pen complete the equipment.

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CHAPTER XIV

EQUINE EPIZOOTIC LYMPHANGITIS

EPIZOOTIC lymphangitis is a chronic, progressive, infectious disorder of the solipeds, involving the skin, the subcutis, the superficial lymph nodes and certain mucosae in which the regional lymph nodes may also participate. It is further characterized by suppuration and ulceration of the parts involved.

The principal areas of distribution of epizootic lymphangitis are to be found in the countries adjacent to the Mediterranean sea, but the disorder is also frequently observed in Russia, various parts of the Asiatic continent and islands, and in sections of Africa more or less remote from its more northern regions. The malady has, from time to time, appeared in other parts of the world such as Germany, Sweden, Denmark, Belgium, England and the United States. It was first observed in southern Europe during the earlier decades of the nineteenth century.

Regions of the body most exposed to cutaneous traumata and abrasions, such as the legs, withers, shoulders, neck, udder, sheath and scrotum, are favorite sites of the infection.

In its most typical forms, the symptoms of epizootic lymphangitis closely resemble those of farcy. Hence, the disorder has often been designated as "pseudo-farcy" or as "benign farcy." Subcutaneous nodules appear, commonly arranged in chains following the course of the lymph vessels. These may remain as painless, indurated small tumors, but more commonly they soften, the hair which covers them disappears and by rupture they discharge a thick, tenacious, yellow, honey-like pus, often mixed with blood. After the rupture of the nodules, crater-like ulcers are formed, having a raised, serrated margin and a red, granulating base. In spite of active granulation, they show but little tendency to heal.

In the majority of the cases the disorder is not accompanied by constitutional disturbances; there is no fever and the appetite is not impaired.

Only in exceptional cases does the morbid process remain local-

ized; it is always more apt to become extended either by the continuity of the tissues or by auto-inoculation brought about by scratching, licking, rubbing, etc. The extension from the primary lesions follows the course of the lymph vessels which then assume the appearance of serpentine, rosary-like, hard cords. The regional lymph nodes may thus become involved.

When the disease affects a mucous surface, nodules form, and these, more rapidly than the cutaneous ones, form ulcers, which may very closely simulate those seen in glanders.

The malady is characterized by a marked chronicity. On the whole it is rather benign, but with the involvement of many parts, the final issue may be fatal. The mortality rate is commonly estimated at 10 per cent.

The more conspicuous lesions are always superficial, and with the exception of the involvement of the mucosae of the vagina and of the upper air passages, are, as a rule, not encountered in the internal organs. In rare cases, tissue damage associated with the infection has been observed in the lungs and in the intestinal mucosa.

The cutaneous and subcutaneous nodules, as well as the involved lymph vessels, are surrounded by a proliferating, fibrous tissue. In a certain number of the more advanced cases the subcutaneous fascia is diffusely proliferated, edematous, sometimes gelatinous and may eventually present ulcerative masses, with fistulous canals and abscesses. In such cases the tendon sheaths and the capsular ligaments of joints may share in the thickening. The nodes receiving the lymph drain of such areas are swollen and may likewise contain purulent foci.

Lesions of the mucosae may take the form of discrete ulcers. These, however, tend to become confluent, followed by a marked degree of tissue damage. Such areas may granulate exuberantly and then show conspicuous fungoid masses of growth.

Although in the majority of the cases a curable disease, epizootic lymphangitis is of a considerable economic importance and particularly so in its more firmly established areas of distribution. With a formidable morbidity rate, its stubborn, chronic course, the relatively high cost of treatment and care and intercurrent complications, the malady is capable of inflicting a very tangible amount of damage.

Susceptible Species.—Epizootic lymphangitis, under natural conditions, is observed only in horses, mules and asses; cases in cattle have been reported from Japan, but from there only.

Artificial transmission to the solipeds has been successfully achieved, but this is by no means readily accomplished. In cavias and rabbits the subcutaneous inoculation of pus caused only local abscesses without further extension to other parts. A successful transmission to dogs has been reported, and cases in man have been observed.

The Micro-parasite of Epizootic Lymphangitis.—The micro-parasite etiologically associated with epizootic lymphangitis is the blastomycete *Cryptococcus farciminosus,* discovered by Rivolta in 1873. In unopened abscesses the micro-organisms are present in pure culture.

Cryptococcus farciminosus is characterized by a marked resistance to external influences. It tolerated an exposure to direct sunlight for 5 days and survived the action of a temperature of 65° C. for 1 hour. The exposure to a temperature of 80° C. killed the parasites within a few minutes.

Contact for 15 minutes with a solution of phenol (5 per cent) only attenuated the micro-organisms, but failed to bring about their destruction. In a solution of formaldehyde (1 per cent) and in one of mercuric chloride (0.2 per cent) they did not survive an hour's exposure.

The cryptococci present in pus and contained in an antiformin solution (50 per cent) showed no appreciable cellular damage; even after being kept for 12 hours in a 7 to 10 per cent solution of this substance the organisms were still alive and capable of reproduction.

In cultures, the cryptococci appeared to be more vulnerable and were killed after 1 hour in a phenol solution (1 per cent), in a formaldehyde solution of a similar concentration and in one of sublimate of 0.02 per cent. A 3-hour exposure to antiformin (3 per cent) also destroyed them.

Cultures were killed in 5 minutes by gaseous sulphur dioxide of 18 volume per cent concentration, but suspensions of 5, 10, or 20 per cent calcium-hydrate showed no effect on them after a 3-hour contact.

The cryptococci remained alive in a stable for 6 months after the last infected animal had been removed from it and caused the disease in a healthy horse coming from a stable where epizootic lymphangitis had not occurred.

Modes and Vehicles of Infection.—In spite of the difficulties encountered in attempts to transmit epizootic lymphangitis by artificial means, it is quite apparent that under natural conditions the malady may spread in an exposed stable or equine population with

relative rapidity. How transmission takes place under such conditions has not been definitely ascertained. There is consensus of opinion that the causative organism is introduced as a wound infection, and that small abrasions and wounds serve as ports of entrance for the cryptococcus.

Horses may infect one another by licking or biting, but it is more probable that the disease is transmitted through the agency of soiled objects coming in contact with the traumata mentioned. As such, bedding, stable filth and dust, stable partitions, mangers and watering troughs, blankets, saddles, harness and grooming utensils are apt to play a part as vehicles.

Transmission by copulation has been observed, and flying insects have been suspected to act as mechanical carriers, but the fact has not been proved. The periods of incubation observed in epizootic lymphangitis show wide variations, ranging between about 2 weeks and 6 months.

Factors Favoring Infection.—The occurrence of epizootic lymphangitis is not modified by many factors. Age and breed exercise but little influence on susceptibility. It has been noted, however, that the malady appears to be less severe in warm-blooded horses than in those of a more lymphatic disposition, and that Algerian mules recover more readily than similar animals introduced into northern Africa from France.

The incidence of the malady appears to be affected by meteorologic influences. It is less frequent during the hot and dry months of the year and is more commonly observed in the course of the colder and rainy season. A humid climate apparently favors the infection.

Lack of grooming and other inadequate care of the skin tends to promote the introduction of the disease, and vigorous animals in a good state of nutrition recover more readily than those in a depreciated state of health and constitution.

Recovery from epizootic lymphangitis leaves the animal with a high degree of immunity, which, however, develops very slowly. Attempts to engender immunity by artificial means have thus far not resulted in a method applicable to sanitary practice.

In Algeria, animals showing the typical scars which may be observed after recovery from the malady command, on that account, a higher price than those not provided with such a badge of immunity.

Prophylaxis.—In countries which, so far, remained exempt from the disease or wherever else the treatment and adequate segregation

of the affected animals are not possible, the immediate destruction of the cases is advisable.

In areas where epizootic lymphangitis is of more or less frequent occurrence and where the destruction of the cases is not mandatory, all affected animals should be rigidly segregated. Stables which they have occupied, as well as all objects used in the care and treatment, should be thoroughly cleaned and disinfected. The personnel in charge of such animals should not be employed to attend the healthy horses and mules of the establishment. The latter should be kept under constant surveillance, and incipient cases should at once be subjected to treatment and also be isolated.

The quarantine restrictions enforced in affected districts should not be withdrawn until 6 months after the removal or cure of the last case.

Animals undergoing treatment should, as much as possible, be prevented from scratching or licking themselves in order to remove the danger of auto-infection, and care should be exercised that apparently cured animals do not serve as carriers of the disease.

In countries where the disorder has already established itself, epizootic lymphangitis should be included among the reportable diseases. Such a measure was followed by excellent results in South Africa. Under its operation incurable cases are destroyed, their owners reimbursed and the other sick animals subjected to segregation, treatment and observation.

The prompt antiseptic treatment of abrasions and wounds tends to restrict the infection hazards incurred by exposed animals.

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CHAPTER XV

ACTINOMYCOSIS

THE name actinomycosis has been given to a chronic, infectious, but not contagious disease occurring in cattle and swine, but less frequently observed in the other domesticated animals. It is caused by a fungus, probably by varieties of fungi belonging to the genus *Streptothrix* which have as their optimum habitat a number of cultivated or wild grasses.

As the disease occurs in animals it expresses itself by connective tissue proliferation, tumefaction and persistent as well as progressive processes of suppuration. The lesions characteristic of the disease may be found in all organs and parts of the body, but in cattle, at least, they most frequently are found to occur about the mouth, the jaws, the throat, and the neck, whereas the mammae and the tonsil are the most common seats of the disease in swine. The peculiar location of the lesions about the entrance of the digestive canal often leads to difficulty in alimentation and to a subsequent state of malnutrition.

Actinomycosis is commonly a sporadic disorder but may, here and there, assume an enzootic character; and localized outbreaks of the disease have also, but rather exceptionally, been observed.

The disease is encountered in many parts of the world with varying degrees of frequency. Certain centers of infection are mentioned in literature; these are apt to be associated with regions subject to inundation or having a rather heavy annual rainfall.

The Virus of Actinomycosis.—It is more than probable that the clinical or pathological phenomenon designated as actinomycosis may be caused by a number of biologic factors, more or less varying according to locality. They may be classed under the genus *Streptothrix,* differing in cultural characteristics in their optimum requirements for growth and in their resistance to external influences. The best known among these organisms are *Streptothrix actinomycosis, Actinomyces bovis, Nocardia bovis, Oöspora, Cohnistreptothrix israeli,* and the actinobacillus. The former is more commonly encountered in the

actinomycosis of Europe and North America; the latter is frequently identified with actinomycotic lesions in Argentina and has also been observed in other parts (Canada, France, Sweden). Their precise relation to one another has not been definitely established, and their comparative frequency is not well known.

The most important quality which they have in common is that when introduced into animal tissues they are capable of exercising a degree of pathogenicity resulting in the development of the lesions peculiar to the disease.

Generally known under the name of "ray fungus," the organisms are widely distributed in nature and may be found in the soil and water and on the vegetation. The species and varieties belonging to the group are essentially and primarily parasites of plants and more particularly of wild and cultivated grasses and grains.

The propagation of the various forms is enhanced by moisture, either associated with poorly drained lands or rendered available by excessive rainfall. Some forms are distinctly aerobic, others anaerobic or facultative to both conditions.

The better-known forms consist of a mycelium of profusely branching threads which in some respects show a behavior similar to that of gram positive bacilli. As found on the vegetable hosts aerial spores are detached from the mycelial threads, but such spores are not encountered in the animal tissues. In contact with the latter, the threads on their free extremities form the characteristic gelatinous clubs which both in the tissues and the pus constitutes a distinguishing feature of diagnostic importance. The radiating arrangement of the club-like endings is responsible for the name actinomyces or ray fungus.

Accounts of the resistance shown by the organisms to external influences vary, and this divergence in behavior probably is associated with specific or varietal peculiarities.

On the whole, the spores are very resistant to drying, surviving in storage for from 1 to 6 years. Solar radiation for more than 6 hours failed to kill the spores contained in bouillon, but their destruction was complete when the exposure lasted for more than 14 hours, although the fact that during this period the spores had commenced to sprout may have been accountable for this result. In another observation an exposure to the rays of the sun for 238 hours failed to damage spores kept in a dry condition.

In some instances the spores were so resistant to heat that boiling them for 14 minutes failed to kill them, but the spores of other

varieties were less refractive and were destroyed by an exposure of 5 minutes to a heat of 75° C.

The resistance to heat of the mycelium is less marked; in the case of the common *Actinomyces bovis* the threads were killed when heated to 60° C. for a period of 5 minutes.

A 5 per cent solution of phenol failed to affect the spores, but they were killed by a 0.1 per cent solution of sublimate after an exposure of 5 minutes.

Susceptible Species.—The disease is most commonly encountered in cattle and swine, but is also seen in man, horses, sheep, goats, deer, llamas, guanacos, elephants, dogs and cats as well as in tapirs and other wild animals.

Modes and Vehicles of Infection.—In the light of our present-day knowledge of actinomycosis, it can scarcely be doubted that practically all the cases acquired the organisms present on parts of graminaceous plants. Direct-contact infection between one animal and another probably never takes place.

The infectivity of the actinomyces apparently becomes so impaired in the course of their development in the animal tissues that even by artificial inoculation it is extremely difficult to transmit the disease.

In a few instances the disease has apparently been reproduced experimentally, but its course in such cases was usually non-progressive and its character benign. Most experimenters failed to transmit the disease by inoculation either with cultures or with material of animal origin. The form of the disease designated as actinobacillosis appears to be more readily inoculable.

That inoculation results varied was probably due to varietal peculiarities of the ray fungi used. The consensus of opinion is that, at least in the spontaneously occurring forms of the disease, it is not transmitted from animal to animal.

In some early American experiments reported by Salmon, 21 healthy cattle were turned in among a group of animals affected with actinomycosis, but after an exposure lasting for 4 months, no lesions could be found during the life of the normal cattle or when they were examined after slaughter.

The infective fungi are those that grow on grasses and grains, and they are inserted into the tissues by means of the beards of the plants. This takes place especially during the process of mastication and deglutition when infested beards or hard, dry pieces of stems or straw penetrate the mucosa of mouth and pharynx, or find their way between the molars and into the alveoli. This course is particularly

suggested by the fact that the lesions in the preponderating number of bovine cases are found to be associated with the mouth, the jaws, the pharynx and the upper part of the neck.

In swine also these parts are not uncommonly involved; in addition, the contact with fungus-infested litter appears to be responsible for the frequent occurrence of mammary actinomycosis in this species.

Various traumas may permit the entrance of the ray fungus, and especially post-castration actinomycosis was observed in horses, cattle and swine. Infective dust carried by the inspired air may account for the occasional occurrence of primary pulmonary actinomycosis.

The progress of the infection process is generally a slow one, and in some cases, at least, the organisms may remain in the tissues for long periods without giving rise to manifest lesions. It is quite possible that the process of pathogenesis is not altogether a simple one and that the simultaneous presence of certain bacterial species tends to promote the disease-producing action of the primary etiologic factor. The presence of such foreign bodies as the barbs and beards of the grasses is commonly regarded as a potent contributory factor.

After the initial introduction of the ray fungus the tissues react by a connective-tissue proliferation and by the accumulation of migratory cells. The lesions are extended centrifugally, and small filaments of the mycelium may be transported by phagocytic leucocytes and thus give rise to new foci of the disease. That infective elements may be carried by the blood stream is indicated by the rather rare cases of generalized actinomycosis.

Factors Favoring Infection.—There can be no doubt that influences which tend to favor the growth of the fungi on their vegetable hosts promote the occurrence of the disease. For this reason, actinomycosis is more frequent during or after prolonged wet weather as well as in regions where poorly drained land is a common topographic feature.

The period of dentition and the oral abrasions incidental thereto favor the possibility of infection, and hence the age factor exercises a certain influence in the promotion of actinomycotic infection.

For obvious reasons, a dry-feeding régime must also be regarded as a factor favoring infection, and animals subsisting on wild or meadow hay and straw, as a rule, show a higher actinomycosis incidence than those which are kept at pasture.

Prophylaxis.—The prevention of actinomycosis by any systematic effort would be extremely difficult on account of the general distribution of the etiologic factors and would, in many instances, require

radical changes in the prevailing methods of agriculture and the feeding of livestock.

The sporadic occurrence of the disease among a livestock population and the relatively small number of cases compared with the preventive measures which would be required to be taken, as a rule, renders special prophylactic efforts inadvisable on economic grounds. In general, it is less costly to deal with actinomycosis clinically than to institute revolutionary changes in animal husbandry as a means of prophylaxis.

The usefulness of exterminating such particularly noxious grasses as *Hordeum murinum* and *H. jubatum* cannot be denied or even doubted, and the substitution of legume hays for straw, wild hay or meadow hay is quite advisable wherever this can be economically accomplished.

To the economic benefit derived from the introduction of alfalfa as a forage plant and to the more general use of silage in some of the American prairie states, the gradual reduction of actinomycosis morbidity must be added as a supplementary advantage.

The grinding of such grains as barley and spelt used for feeding purposes reduces the infection danger, and the same is true of the preparation of such feeds by steaming or soaking. However, the use of such methods for the sole purpose of preventing actinomycosis can be recommended only where the disease is unusually common or where especially valuable animals are to be protected. On the whole, the management of actinomycosis is more the task of the clinician than that of the sanitarian.

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CHAPTER XVI

TUBERCULOSIS

General Considerations.—Essentially a corollary of civilization and domestication, no other disease of animals has assumed a wider distribution or has become a more constant source of damage to animal husbandry than tuberculosis. Since the middle of the nineteenth century it has developed into a major problem of livestock sanitation, the solution of which became an imperative necessity as its serious inroads into the food-producing animals became more definitely known.

The disease affects all species of domestic animals with a varying degree of intensity and frequency. The heavier losses are sustained by cattle, swine and poultry, but the disease is also encountered in horses, goats, sheep, dogs and cats. It has been observed in the camel and the elephant, and among wild animals of menageries and zoological collections, it commonly assumes the nature of a real scourge.

Following the channels of commerce, tuberculosis has obtained a foothold in practically all parts of the world where animal husbandry is practiced with any degree of intensity.

The susceptibility of children to bovine tuberculosis infection has caused cattle tuberculosis to become a factor in the preservation of the public health in many countries.

The Virus of Tuberculosis.—The possibility of effective measures against tuberculosis was delayed until the fact of its infectiousness was firmly established by Villemin (1865) and until the specific etiologic factor, the *Bacillus tuberculosis,* was discovered and described by Koch (1882). Those discoveries led to the acquisition of more accurate knowledge of the nature of the disease and the development of the exact methods of diagnosis upon which a practical prophylaxis could be based.

A strictly obligate parasite, the bacillus of tuberculosis, in its evolution as a pathogenic factor, developed certain definite host relations which gave rise to the varieties or types largely peculiar to the

animal species in which they find an optimum soil for their propagation. These types show distinct differences not only in pathogenicity but likewise in their manner of growth on artificial media. Their relations to the tuberculoses of the various animal species are, however, not strictly confined to the ones in which they find the most favorable conditions for growth and propagation.

Thus it is found that the bovine type of tubercle bacillus is capable of causing tuberculous disease in practically all mammals. The type peculiar to man, though not endowed with the marked pathogenicity for as many mammals as the bovine type, is capable of disease production in a number of species. The type responsible for the disease in birds is also an important factor in causing the disease in swine and in some other mammals as well.

Host Species.—The animal species in which tuberculosis has assumed the proportion of an economic problem are cattle, swine and the various species of domesticated birds. The tuberculoses of those animals constitute the major part of what may be designated as the tuberculosis problem. Aside from the relatively small number of proved transmissions from man to animals, the tuberculous infections of cattle and poultry are the sources from which the other species, not specifically named, derive theirs.

Modes and Vehicles of Infection.—As an obligate parasite the tubercle bacillus propagates itself only in the body of its hosts. There it is especially associated with the lesions, although bacilli may also be found in parts or organs not presenting the classic tubercle formation. It is especially during the process of tissue destruction and of the softening of the lesions that the bacilli are set free and that they can find their way into secretions and excretions, which serve them as vehicles by which they escape from the body of their host. This process of virus elimination constitutes the "open case," whereas the animals in which the lesions are not disintegrating and in which the virus is imprisoned are designated as "closed cases," a distinction which forms the basis of certain measures of control.

Among the channels through which "open cases" eliminate their bacilli, the respiratory tract in pulmonary tuberculosis is perhaps the most important one. The bacilli contained in the mucus and muco-pus are cast out during fits of coughing or by the more constant and slower discharge through the nose. Much of this material is swallowed and undergoes digestion; the bacilli it contains, largely resisting the action of the digestive enzymes, are apt to appear in the feces in a viable and fully virulent state. Bacilli escaping from

TENTATIVE REPRESENTATION OF THE HOST RELATIONS OF THE THREE TYPES OF TUBERCLE BACILLI

Host species	Bacillary types			
	Bovine	Human	Avian	Atypic
Man	++	+++	+ (*)	(*)
Bovine	+++	0 (*)	+	(?)
Swine	+++	+ (*)	++	+ (*)
Horse	++	(?)	+ (*)	+ (*)
Sheep	++ (*)	0 (*)	+ (*)	(?)
Goat	+++	0 (*)	0 (*)	(?)
Cat	++	0 (*)	+ (*)	(?)
Dog	++	++	0 (*)	(?)
Cavia	+++	+++	0	(*)
Rabbit	+++	+	+++	(*)
Fowl	0	0	+++	(*)
Parrot	+++	+++	++	(?)

+++ Full virulence.
++ Moderate or conditional virulence.
+ Slight virulence.
0 Avirulence.
(*) Data insufficient for definite conclusions.
(?) Unknown.

disintegrated lesions of the liver and intestines have the same means of exit.

In tuberculosis of the female reproductive organs the vaginal discharge commonly contains virulent bacilli. The semen may become the vehicle of the organisms when the testes harbor disintegrating lesions. In tuberculous disease of the kidneys and the urinary tract the urine may become the medium by which they find their way into the environment.

As a vehicle for tuberculous infection, milk occupies a prominent position. Always virulent in the case of mammary tuberculosis, it frequently has been found to contain bacilli in cases of the disease in which no appreciable udder lesions are present.

As a rule, tuberculous infection occurs in an indirect manner, and a direct transmission from animal to animal is rather exceptional. More commonly, such infection comes about when virulent secretions or body wastes are expelled in the immediate environment where they can contaminate food, drink and other substances.

Small droplets of discharge coughed out may be directly inhaled, when suspended in the air, or they may settle on materials taken in by the animals as food.

Feeding and watering utensils soiled by virulent mucus expelled by the respiratory tract also constitute a means by which tuberculous disease may be transmitted.

Virulent ejecta from the lungs, intestines or other organs, deposited in stables, subjected to desiccation and subsequently ground to dust and deposited on food and drink likewise are well-recognized means of indirect contact.

Infected milk fed to calves and other susceptible animals is a common means of transmission for tuberculous infection.

The alimentary and respiratory tracts are the most common portals by which the tubercle bacillus invades the body. Far less important as avenues of penetration are the genito-urinary tract, skin abrasions, the eye and the open navel wound, while intra-uterine infection, once considered to be an important factor, is so infrequent in its occurrence as to be without practical importance.

In the transmission of avian infection, soil constantly receiving the virulent feces of tuberculous fowls is probably the most potent factor owing to the feeding habits of the susceptible species.

Factors Favoring Infection.—Even in the more susceptible species, positive tuberculous infection is largely dependent on the number of bacilli which gain entrance into the body. Initial infection takes place either through the constantly repeated entrance of a relatively small number of bacilli (thus through a more or less prolonged exposure), or by the single invasion of a massive dose of the infective agent. The occasional entrance of a minimum number of bacilli is probably a negligible factor in the etiology of the disease.

In a large measure, the hazard of tuberculous infection is determined by the nature of the environment. If the latter favors a constant and prolonged exposure or makes possible an invasion by overpowering numbers of bacilli, a conspicuous morbidity is apt to be the result, whenever a tuberculous animal is introduced. Density of animal population is a potent factor in the spread of the disease; the concentration of animals and the resulting possibility of close contact with infective materials incidental to stabling creates conditions which are particularly favorable to infection spread.

The enzootic character of tuberculosis in regions where prolonged stabling is enforced by an inclement winter climate is directly due to this exposure to a concentration of infective material. To this

must be added the baneful influence of bad hygienic conditions under which the virus is more apt to remain intact and infective and which increase the susceptibility of the animals by adverse action on their metabolic functions.

In addition to the mischievous effect of unhygienic housing or other unfavorable conditions associated with the environment, the possibility of tuberculous infection being favored by predisposing factors inherent to the animal body itself must also be given weight. Faulty body conformation, under-nourishment and previous disease help to establish a favorable soil for the tuberculous virus, and the depreciation of body vigor incidental to such influences as a heavy secretion of milk and the exclusion of the influences of outdoor air and direct solar radiation are likewise apt to increase the liability to tuberculous infection.

Morbidity.—The understanding of the relation and behavior of the tuberculous parasite to and toward its host, and vice versa, essential to the solution of the tuberculosis problem, must be supplemented by definite information concerning the epizootic features of the disease in any section before the necessary measures of control and eradication can be intelligently determined upon. Tuberculosis of animals, unlike certain other transmissible diseases, has thus far not shown a self-limiting character. In this respect it differs from tuberculous infection in man, which even before the day of rational prophylaxis began to show evidence of decline.

With the presence of virus in a given animal population, tuberculosis tends to spread, the rate of morbidity slowly growing with ever-increasing intensity. Slowly as the initial infiltration of the infection may be, the morbidity of tuberculosis does not remain stationary, and when not checked by repressive measures its incidence always increases. Many factors not always accurately known influence this rate of increase, but the few data available indicate that for instance in a bovine population of more or less constant numbers the morbidity rate may double itself approximately every 15 years. In avian tuberculosis this increase operates with even greater speed.

The morbidity rate (the percentage of tuberculous animals in the total number) as well as the rate of prevalence (the percentage of herds or premises infected) to a large extent must be taken into consideration when methods and means of control or eradication are to be planned and determined upon. In a region with a bovine tuberculosis morbidity of 1 per cent and a prevalence rate of 10 per cent, the measures to be taken can be very different from those

necessary in a country with a morbidity rate of 30 per cent and a prevalence rate of over 60 per cent. The item of cost alone will be a compelling factor in the choice of ways and means.

Prophylaxis.—In the prophylaxis of tuberculosis the means to be employed may include any or all of the following steps: (1) the erection of barriers surrounding non-tuberculous herds and flocks; (2) the maintenance of environmental conditions favorable to animal well-being and adverse to the virus or to its dissemination; (3) the elimination of infection sources; (4) the destruction of the virus; (5) the establishment of a resistance to tuberculous infection by immunization of animals concerned.

Erection of Barriers.—In order to maintain tuberculosis-free herds and flocks, relatively simple measures are sufficient, provided that the environment (stables, etc.) has not within a recent period been contaminated with the ejecta of animals infected with the disease.

The barriers to be erected pertain especially to provisions made in regard to new animals to be introduced, and to foodstuffs purchased from outside sources.

New acquisitions of cattle, swine and poultry should always be challenged by means of a tuberculin test. Until such a test has been or can be made under conditions which warrant full confidence in the result, the animals should be kept in isolation. In the case of poultry, the introduction of adult birds should be avoided as far as possible and preference given to the purchase of hatching eggs or baby chicks.

The challenge of foodstuffs pertains particularly to milk or the byproducts of creameries and cheese factories. Unless originating from herds known to be tuberculosis free (accredited herds in the United States), the innocuousness of this type of food must be secured by pasteurization or sterilization. This may be done at the place of origin or at the final destination. Creameries and similar industries are usually better equipped for sterilizing or pasteurizing than establishments which subsequently handle these byproducts. The effectiveness of the measures should be controlled by adequate supervision.

Other foodstuffs which should not be fed without challenge are garbage and abattoir offal. Swine and poultry should have no access to such materials unless its freedom of active tuberculous virus has been secured by adequate sterilization. The danger of human tuberculosis being transmitted to cattle and swine is relatively slight, the human type of tubercle bacillus possessing but little virulence

for cattle, although in a more marked degree for hogs. Dogs are, as a rule, quite resistant to tuberculosis; but in the cases recorded the human bacillary strain was found as often as the bovine one. Human tuberculosis is apparently not readily transmitted to cats, which, however, have a moderate susceptibility to bovine infection. In the infrequent cases of tuberculosis of goats and sheep the bovine type of bacillus appears to be the etiologic factor. The same is probably true of tuberculosis of the horse.*

On general principles, a possible infection source associated with human cases should also be effectively closed, however slight the hazard may otherwise be. In this connection, consideration must also be given to the possibility of man being affected with tuberculosis due to bacilli of other than human types or to organisms of atypic virulence and with a wider range of pathogenicity.

Hygienic Environment.—It will generally be found that the state of environment influences the progress of tuberculous infection among animals as well as among man. Stabling is a most potent factor in the spread of bovine tuberculosis, and the more closely indoor conditions resemble those of the outside the more favorable their influence on the morbidity rate will be.

To a less degree this is true in the case of the tuberculoses of swine and poultry, owing to the fact that on account of the feeding habits of those animals, they commonly contract their infection through the fecal contamination of yards and feeding and drinking utensils. In the case of the species mentioned, thus, the avoiding of contaminated soil, the periodic rotation of pig and poultry yards and clean methods of providing feed and water will materially aid in the general scheme of prophylaxis.

Adequate ventilation and lighting of enclosed spaces favor the more rapid destruction of tuberculous virus present, and especially should those measures be given weight when dealing with the bovine disease.

Among the hygienic measures related to the environment a place must be given to the separation of animal species between which tuberculosis is intercommunicable, unless freedom from tuberculous infection can be definitely established.

Elimination of Infection Sources.—The primary source of tuberculous infection is always the tuberculous animal. Whether the infected animal is an actual distributor of the virus (open case) or

* Cases of avian tuberculous infection in sheep have more recently come to light.

a potential one (closed case), its elimination will remain the most effective measure in any scheme of prophylaxis.

The refined methods of diagnosis based upon the specific reaction to tuberculin and the bacterioscopic identification of the tubercle bacillus in the various body discharges have firmly established themselves in sanitary practice as the means of designating those infection sources with remarkable precision.

They constitute the pivot upon which the control, suppression and eradication of animal tuberculoses turn and more especially so in connection with the bovine disease. In the recognition of herd and flock infection, autopsy and meat inspection reports also supply valuable data.

Destruction of Virus.—The most essential step in the prevention of tuberculosis is the destruction of virus present either within the animal body or in the environment frequented by susceptible animals. As it is not possible to bring about the sterilization of the living animal, only one choice is left, and that is the destruction of the carrier animal itself. This view has been widely accepted in sanitary practice.

In countries or herds with a low morbidity rate or in cases in which only animals of inferior value are involved, this can usually be carried out in a radical manner. Its application may, however, meet with unsurmountable difficulties in countries in which morbidity and prevalence rates have become so high that the radical elimination of all infected animals would cause a serious shortage of animal foodstuffs or would involve financial outlays which cannot be sustained by the national wealth. In such cases, the more radical efforts must, for a time, remain confined to such animals as can be proved to be the most active distributors of virus or even to mere measures of segregation.

The virus found outside the animal body is that which is present in the immediate environment frequented by tuberculous animals. It must always be reckoned with and especially so after the elimination of the latter.

Commonly protected by being contained in the various ejecta and discharges of infected animals, it must be destroyed in stables and stable equipment such as mangers and drinking troughs by disinfection. The choice of disinfectant may be regarded as a matter of minor importance provided its application is preceded by a complete removal of all filth and by a thorough process of cleaning.

The construction of stables as well as the type of building ma-

terial are of the greatest importance to the effectiveness of the cleaning and disinfection. The more impervious material always permits the highest degree of virus destruction. Old wooden buildings of defective construction must often be abandoned for a long period or replaced by more adequately sanitary structures.

A special position is occupied by the soil of poultry yards and pig pens frequented by tuberculous animals. It is apparent that the virus contained in the soil may retain its viability and virulence for prolonged periods, and as the disinfection of the soil has no practical feasibility, their temporary abandonment by animals and their use for crop growing is, no doubt, the best course to pursue.

Immunization.—The fact demonstrated by Koch, that animals already tuberculous are manifestly more resistant to a subsequent virulent inoculation than those free of the disease, has inspired many investigators to make attempts to bring about a degree of immunity to spontaneous infection. Those efforts found further encouragement in the observations first made known by Marfan, namely: that scrofulous children, who had completely recovered before the age of fifteen years was reached, rarely developed an active pulmonary tuberculosis.

A considerable number of investigators have approached the problem of bringing about a resistance to tuberculosis by divers methods, but although their results were often encouraging and of manifest scientific value, they did not succeed in evolving a method sufficiently efficacious and safe to become applicable in sanitary practice. One chief difficulty was the finding of a bacillary strain with immunizing properties and yet so completely and so permanently avirulent as to be harmless to the animals inoculated or to those immediately associated with them.

The latter difficulty may or may not have been overcome by Calmette and Guérin in their bacillary strains by continuous cultivation on bile medium. Their experimental evidence is of a nature to inspire a degree of optimism not warranted by prior efforts. However, more extensive trials will be required before the practical value of their method can be definitely appraised. Until then a suspension of judgment will be indicated.

Prophylactic Practices.—The prophylaxis of tuberculosis may be attempted by either private or public efforts. Experience has shown that the ultimate success can be realized only when all measures taken are based upon a voluntary co-operation of livestock owners. After all, they remain the most important factor in the solution of the prob-

lem. An enlightened and sane public opinion thus constitutes a prerequisite condition upon which the conquest of tuberculosis is especially dependent.

Especially when public efforts of eradication are in contemplation it is quite imperative that the livestock-owning public be placed in possession of the most essential facts concerning the nature of the disease, its economic and public-health importance, the knowledge upon which the measures proposed are based as well as the steps to be taken in order to bring about the consummation of the task.

By the printed page of pamphlets and circulars, by the spoken word in conferences, must the facts relating to tuberculosis be made the common property of those primarily concerned in the problem. General information is the soundest foundation upon which general prophylaxis must be built, and sufficient time must be taken for its dissemination.

This preliminary and preparatory phase of an anti-tuberculosis campaign may be undertaken either by organizations of livestock owners, by herd book associations, by co-operative creameries, by the public agencies having to do with the dissemination of knowledge pertaining to agriculture or by the veterinary staff which later on is to engage in the actual work.

In the light of the knowledge now available, it cannot be doubted that the best results can be obtained only when concerted action against tuberculosis is undertaken under government auspices. This favors intelligent co-ordination of the measures to be taken. Based upon voluntary co-operation, such a plan renders it more readily possible to place disinterested counsel and experienced guidance at the disposal of the livestock owner; under any system of eradication which must largely depend on the partial reimbursement from the public treasury for cattle slaughtered, official supervision is quite essential to ultimate success.

The exercise of the government police power cannot be dispensed with in the prophylaxis of tuberculosis. The movement of tuberculous animals must be supervised and restricted to those with a slaughtering establishment as their immediate destination. Such regulations as those which prescribe the admittance of tuberculosis-free cattle into the various states, the 60-day retest and other restrictions rendering the sale and distribution of tuberculous animals more difficult have had a most favorable influence in stemming the great flood of infection into relatively free areas, and for a long time they were the only protection of their cattle herds.

The sanitary supervision of milk supplies and dairy herds by municipalities and other units of public administration has resulted in the eradication of many centers of infection, and the meat-inspection service maintained at slaughtering establishments must not only be credited with important sanitary and economic achievements, but also with having furnished valuable data of a statistical nature without which a thorough understanding of the problem in hand would be impossible.

The functioning of government power has made possible the establishment of a system of accreditization of tuberculosis-free herds and areas, which in the United States so largely contribute to the safety of buying breeding animals for herd improvement and replenishment.

All the measures mentioned are more or less essential to the success in coping with the general economic and sanitary problems associated with the animal tuberculoses and cannot be dispensed with as long as the task remains unfinished.

Tuberculosis of Cattle.—The prophylaxis of bovine tuberculosis presents two principal phases of equal weight and importance, namely the protection of the non-infected animals and the control and eradication of the disease in herds where the infection has already established itself.

With a view to the many possibilities of tuberculous infection, the need of constant vigilance on the part of the owners of tuberculosis-free herds and of their veterinary advisers cannot be over-emphasized. Not only should a hygienic environment be rigorously maintained, but it is always a matter of prudence to challenge periodically the health status of the herd by tuberculin tests. Early detection of tuberculous infection always permits its prompt elimination at a minimum of cost and annoyance.

If freedom from tuberculosis can be clearly established, it becomes a relatively simple matter to maintain this condition indefinitely.

The value of recruiting a herd from its own offspring is at once apparent, and it should be largely managed with this object in view. When new animals must be introduced, they must be either selected from tuberculosis-free (accredited) herds or they must be proved to be free of infection by a negative tuberculin test prior to their acquisition. If there exists the least doubt as to their origin or their history with regard to previous tests, they should be tested again after a lapse of 60 days, during which period they should remain in isolation.

Cattle returning from show circuits must, upon their return, be accorded the same precautionary treatment; milk and milk products from outside sources for calf-feeding purposes are to be subjected to pasteurization.

In the face of existing infection, the prophylactic methods must vary in character in accordance with morbidity and prevalence rates so far as they pertain to the areas in which any attempt is to be made.

Had the degree of morbidity and prevalence been better known before the earlier attempts at control and eradication were undertaken, the results would not have been so disappointing. After the great diagnostic value of tuberculin had been discovered, it was thought that nothing remained to be done but to test all cattle, kill or segregate the reacting animals and thus dispose of the whole problem. In the countries where such a plan was adopted, it could not be carried out to a final conclusion, for more animals reacted than could be taken over by the government, and such a large number of animals would have had to be eliminated that the supply of fresh milk and other food would have been seriously menaced.

The compulsory features of the method and the failure to secure the co-operation of the herd owners by the dissemination of information also contributed to those early disappointments.

With the accumulation of more knowledge and experience, it became apparent that only in a few countries is it possible to proceed against the disease by the drastic measures of the initial attempts. With a low rate of tuberculosis morbidity, an enlightened public opinion and complete freedom of participation on the part of the owners, slaughter on tuberculin evidence is justifiable as the most efficient method of bringing about the desired results. When the morbidity rate is high, however, less radical methods must be followed until such time as more favorable conditions are established.

All plans for tuberculosis control and eradication must be made with regard to the extent of disease infiltration in the countries concerned.

The tuberculosis situation in the United States as a whole has been such that the more radical elimination of tuberculin-reacting animals could be attempted; in 1917 the Congress was able to sanction a definite nation-wide attempt, with the free active co-operation, financial and executive, of the various states, to eradicate the disease altogether, and was able to place the voluntary recourse to slaughter on the part of owners reasonably within their reach.

Prior to that year, several states had, with varying degrees of success, coped with the problem, and the Federal Government had already excluded tuberculous cattle from interstate traffic and had stopped their importation from abroad, unifying to a large extent the efforts applied to the solution of the problem.

Beginning with the voluntary eradication of tuberculosis from the pure-bred herds as important centers of infection, the accredited herd or honor roll plan was evolved, accreditization being conditional on two successive animal tuberculin tests showing freedom from infection. Cattle belonging to such herds are permitted to be moved in interstate traffic without restriction for a period of one year.

When funds became available, as the campaign gained momentum, the work was extended to other types of cattle. As the soundness of the methods followed became apparent, the scheme of clearing entire sections of the country of tuberculous infection began to appeal to those most concerned in the movement, with the result that the eradication from county units found a wide application and accredited, tuberculosis-free areas came to be established. Not only are certain trade advantages thus secured, but in addition the country-wide eradication is hastened and the cost of the campaign materially reduced.

The principal factors which are brought to bear upon the solution of the bovine tuberculosis problem in the United States may be summed up as follows: (1) voluntary co-operation on the part of cattle owners; (2) free expert counsel and supervision; (3) recognition of bovine tuberculosis in its economic and sanitary aspect as a matter of government concern; (4) partial re-imbursement (about two-thirds of actual value) of the owners for cattle slaughtered; (5) co-ordination of private, state and federal efforts.

For reasons already stated, the high tuberculosis morbidity in certain countries compels the adoption of slower and less radical measures, by which the disease may be opposed. Such measures are especially designed to permit a new generation of animals to grow up without exposure to tuberculous infection, while simultaneously the infected parent stock is utilized and exploited as long as the nature of their lesions is compatible with a certain degree of productivity and safety from a sanitary point of view.

The first orderly and well-founded method of procedure was proposed by Bang. It is partially based upon the fact that calves born from tuberculous dams are but very rarely found to be infected at the time of birth, so that, if they can be successfully placed in a

disease-free environment and fed milk and other food free from tuberculosis virus, they must remain exempt from the disease.

After the elimination from the herd of animals which give evidence of being open cases or which are otherwise undesirable from the standpoint of production, the entire number is subjected to a tuberculin test.

The herd is then separated into two groups, one containing the reacting and the other the non-reacting animals. Either the two groups are placed in separate stables, yards or pastures, or the original stable is divided into two parts by means of a partition so constructed as to preclude all intercommunication. The stables or sections to be occupied by the two groups must be subjected to a thorough disinfection before the animals are admitted.

If at all possible, each group should be milked and attended by different personnel, but when this cannot be done the disease-free group should always be milked and fed in advance of the other, and each stable or section should be provided with a separate equipment of utensils.

Within a suitable period after the separation, the non-reacting group is to be subjected to another tuberculin test in order to detect any recent infection which the first test could not yet reveal. After this a tuberculin test every 6 months or even once a year should be made in order to control the efficiency of the segregation.

All calves born to both groups should from the second day on be fed with sterilized or pasteurized milk only. On the first day they must receive the colostrum, as this appears to be indispensable to their health. As this contains an element of hazard for the calves of tuberculous dams, the young are to be subjected to a tuberculin test when they are a few weeks old. Reacting calves must then be eliminated as a matter of course.

The disease-free juvenile herd must be kept in a safe environment as far as tuberculous infection is concerned.

The reacting group of the cattle herd should be gradually reduced in numbers by the slaughter of such animals as become less essential to production. The sooner the tuberculous animals are eliminated without excessive sacrifices the better will be the final results.

If the two segregated groups are sufficiently numerous, separate herd bulls may be maintained. In the event that one bull only is desirable this can be permitted without serious risk, provided that the breeding is done on neutral ground and the contact between the animals involved be not unduly prolonged.

In herds in which only a small minority of the animals fails to show the specific reaction, the method may be profitably modified to the extent that no separation is attempted. The management of the calves must, however, remain as originally prescribed by Bang.

The efficiency of Bang's method has been demonstrated in many herds, and by its rigid application a healthy herd can be built up from badly infected parent stock. On the other hand, it has been proved to be so irksome to herd managers and attendants that it has never enjoyed a marked popularity. In the case of exceptionally valuable breeding animals, it still deserves the most serious consideration when a choice of methods becomes imperative in the face of a high rate of morbidity.

The high percentage of reacting animals encountered in herds in countries with a marked dissemination of bovine tuberculosis and the attendant difficulty of adequately dealing with the problem they present by any of the measures already mentioned, has forced the adoption of another method, more applicable and better suited to a desperate situation arising from the high degree of morbidity.

This method, originally proposed by Siedamgrotzky and given a practical form by Ostertag, by whose name it is now known, is especially employed in Germany.

Ostertag dispenses with the initial tuberculin test and the subsequent separation of the herd in reacting and non-reacting animals. His efforts are concentrated on the prompt elimination by slaughter of the animals with open tuberculosis and the thorough disinfection of their stables.

The method involves a periodic clinical examination of the animals of the herd, supplemented by frequent bacteriologic analyses of their secretions and excretions such as milk, bronchial mucus and other body discharges. When evidence of tuberculosis is encountered in connection with organs communicating with the outside (lungs, udder, genito-urinary tract, alimentary canal), or bacilli are found in any of the discharges, the animals are sacrificed by slaughter at once. No attention is paid to the closed cases of tuberculosis.

The calves are managed as prescribed by Bang, including their control by the tuberculin test. They are kept in permanent separation from the original infected herd.

Under the circumstances in which the Ostertag method finds application, it certainly deserves consideration. By the elimination of the more dangerous sources of infection the volume and speed of

infection spread is reduced, and this reduction may in time render a more radical procedure possible.

The method is, however, not without inherent disadvantages. It involves a heavy expenditure of time and funds for veterinary services, bacteriological examinations and supervision; moreover, it is not always possible to differentiate clearly between open and closed cases.

Ostertag's measures have merit as an initial step in the face of great morbidity, but they have no place in countries where tuberculous infection has not yet deeply infiltrated into the bovine population or where there exists even a moderate degree of dissemination. The effective application of an artificially established immunity is as yet an achievement to be hoped for. With its consummation, the control of tuberculosis even in the worst infected countries would become a probability and its ultimate suppression a possibility. It would starve the infection through lack of susceptible hosts, and, although this may not come about in the immediate future or perhaps not before many years have elapsed, there is warrant for an optimistic attitude and ample justification to give support and encouragement to the workers occupied with the solution of this problem.

In the choice of methods to be pursued in the struggle against bovine tuberculosis, it is well to remember that their value can be correctly estimated only by consideration of the character of the local situation. Ostertag's and Bang's methods are no more suited to deal with the problem as it exists in the United States as a whole than the radical methods pursued here could find application, without risk of failure, in countries with an excessive morbidity rate.

Tuberculosis of Swine.—The problem presented by the prophylaxis of swine tuberculosis differs from the one associated with the prevention of the disease in cattle. Although the transmission of tuberculosis from swine to swine may actually take place, the preponderating number of tuberculous hogs become infected by virus eliminated by animals of other species.

Tuberculous cattle and poultry are the common and more prolific sources of swine tuberculosis, and transmission from human patients, although apparently of minor importance, cannot always be excluded.

The type of infection encountered in swine varies with locality, the prevailing methods of livestock management and the tuberculosis morbidity in cattle and poultry.

The task of dealing with swine tuberculosis is rendered lighter in comparison with the same problem in cattle, by the relatively brief span of life of the preponderating number of hogs. Although this factor may but slightly affect morbidity, it materially reduces the percentage of open cases and the subsequent spread of the disease from swine to swine. It also lessens the importance of segregation and of the systematic application of tuberculin tests.

The influence of housing is not so potent with swine as with cattle, but the feeding habits of the former cause yard infections to play a more important part, swine tuberculosis being largely, if not exclusively, of alimentary origin.

In consideration of the primary sources of swine tuberculosis, their elimination is the chief factor in its prevention. This follows automatically the eradication of the disease from both cattle and poultry. This must be supplemented by rigid attention to the sanitary character of certain types of food commonly offered to swine.

Unless the cattle herd on a given farm is definitely known to be free of tuberculosis, the milk produced by such a herd must not be fed to pigs without being previously rendered safe by sterilization or pasteurization. By-products purchased from creameries, butter factories, cheese factories and dairies must not be fed to hogs in the raw state as long as bovine tuberculosis has not been completely eradicated from the herds contributory to such industries or from the areas in which they operate. Owing to the better facilities to be found in such establishments, the by-products should be rendered safe before they are issued to purchasers. In some countries this is prescribed by law.

For obvious reasons, similar precautions are necessary when garbage, abattoir offal and kitchen wastes are to be used as a food for swine.

The common practice of keeping swine and cattle in the same feeding yards must be discontinued as long as there is no certainty of the yards being free of tuberculous infection.

In its relation to the prevention of swine tuberculosis, the eradication of the disease from the farm poultry flock must be regarded as of importance equal to its elimination from the cattle herd. Owing to the widespread and commonly unsuspected presence of tuberculosis in poultry, steps should be taken to keep the latter effectively separated from swine.

The avian infection responsible for tuberculosis in swine is to a large extent soil-borne, because of the fact that the bacilli deposited

in the soil with the droppings of infected fowls may retain their virulence for considerable periods.

In enclosures occupied in common by poultry and swine, the pollution of feed and water by the body wastes of the fowls constitutes an additional danger, and the decrepit tuberculous bird devoured by pigs cannot fail to be a potent factor in disease transmission.

In swine herds in which the presence of tuberculous infection has been established (abattoir reports), it is advisable to subject the older breeding stock to a tuberculin test, in which both mammalian and avian tuberculin or a mixture of the two should be used. Animals showing a positive reaction must be promptly eliminated by slaughter.

The maintenance of separate enclosures for swine and poultry, the annual rotation of hog lots and poultry yards, permitting the occupation of clean, uncontaminated ground, and the adoption of sanitary feeding and watering methods are likewise of material value in the reduction of infection hazard.

Tuberculosis of Poultry.—The measures to be taken in the prophylaxis of tuberculosis of the domesticated birds, though based upon the same general principles as those directed against the disease in other species, are modified by the character of the host animal concerned, as well as by the prevailing methods of poultry husbandry. Although instances are reported in which mammalian virus was associated with avian infection, it is quite safe, for practical purposes, to assume that the infection by the avian bacillary type only is to be guarded against.

The relatively low value of the individual birds encourages recourse to radical measures of eradication, and the difficulty encountered in the destruction of the virus in contaminated soil will compel their adoption in a considerable proportion of the infected premises as the most efficient solution of the problem.

In the maintenance of tuberculosis-free poultry flocks, the exclusion of adult birds from unknown or questionable sources is a most essential measure, as in most cases the initial infection can be traced to the introduction of such fowls. If new stock has to be acquired, it is safest to do this in the form of one-day-old chicks or hatching eggs.

The probability of tuberculous infection being imported into a flock by such flying birds as pigeons and sparrows must be given consideration, even if there is no great volume of evidence pointing to its importance.

Especial care should be exercised in the disposal of the offal of poultry purchased for the table. This type of material is probably not a common vehicle by which tuberculous infection is introduced into farm flocks, but it is a more potent factor in disease dissemination in the small flocks maintained by the inhabitants of cities and villages. Hence all offal, even if it shows no trace of tuberculous lesions, should be destroyed by burning.

Hygienic environment and sanitary methods of feeding and watering also exercise a beneficial influence on the health of the flock as far as tuberculosis is concerned.

In dealing with a flock already infected, different methods of procedure can be chosen from. The problem may be solved by the slaughter of the entire flock, followed by cleaning and disinfection of yards, houses, and feeding and watering utensils. Owing to the survival of the virus in the soil of the yards, the premises should be left unpopulated by poultry for a considerable period. One year is not too long unless it be possible to place a new flock on uncontaminated ground. In the restocking, preference should be given to recently hatched chicks or to adult birds with a recent negative tuberculin record.

In the case of the average farm flock, preference should be given to the more radical methods of eradication. In its application, the slightly affected fowls or those showing a negative reaction to tuberculin can be used for food, but it is essential that in a rather brief period all birds be eliminated.

A more conservative method of eradication may be chosen for tuberculous flocks in which the preservation of breeding stock of high value is essential. There the use of the tuberculin test can be made the base for separating the flock into a tuberculous and a non-tuberculous group. The former only should be sacrificed, and ordinarily it will be found to be a sound practice to include the old birds in this group.

If possible, the fowls of the latter group should be kept in an infection-free environment. This is frequently difficult on account of the virus remaining in the soil from which the birds can readily pick it up. For the success of this means of solving the problem it is almost imperative to find ground not previously frequented by tuberculous birds.

A repetition of the tuberculin test after the period of one month is recommended in order to determine the presence of any delayed infection.

On the whole, the repeated tuberculin tests, aside from being irksome to flock owners, are not the most practical means of solving the tuberculosis problem among poultry. Too frequently, the bacilli in the soil, left after the elimination of the reacting birds, are apt to defeat the object of the latter measure. Hence, preference may be given to annual elimination of the older fowls, which comprise the greater number of spreaders. In tuberculous flocks the disposal of all fowls at the close of their first egg-laying period will remove the primary infection source. An infected soil will probably remain behind, but the stock of virus which it contains will gradually become eliminated and disappear, because infected fowls will not be permitted to remain long enough to replenish the bacilli present.

The length of time required to eradicate the disease by the above method will vary in accordance with the character of the soil and the amount of bacilli it contains. It seems wise to continue the annual elimination of the older stock for two or three years, after which a tuberculin test may indicate whether or not the practice should be continued. If positive reactions are no longer obtained the fowls may be permitted to remain until they are two years or more old.

The marked prevalence of avian tuberculosis *per se* as well as its common transmission to swine in many sections is warrant for concerted efforts looking toward its control and eradication, comparable with those now generally applied to the disease in cattle.

Tuberculosis in Other Animals.—With the suppression of the tuberculoses of cattle and poultry, other species of domestic animals are practically safeguarded.

Among horses, goats, and sheep, the disease is comparatively rare, and only when they are in intimate contact with tuberculous cattle or are being fed with their milk are they apt to become infected. These dangers can be readily averted by preventing contact or by the use of heated milk for feeding purposes.

Dogs, though showing a considerable degree of resistance to all types of tuberculous infection, are susceptible to both the human and bovine bacillary types, so that the use of milk or slaughter-house offal, as well as contact with phthisical persons, must be regarded as the means by which canines are apt to contract the disease.

Similar factors determine the causation of the disease in cats, although there is evidence that this species is quite resistant to human infection.

Among the household pets, the parrot occupies a unique position through its susceptibility to human infection, which must, therefore,

be reckoned with when contact with a person suffering from pulmonary tuberculosis offers opportunity for disease transmission.

When the existence of tuberculous infection in the horse, the goat, the sheep, and the various household pets is ascertained, the destruction of the affected animals is indicated as the most efficient means of disposing of the problem.

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CHAPTER XVII

PARATUBERCULOSIS

JOHNE'S disease, or paratuberculous enteritis, is a markedly chronic, communicable disorder of cattle, characterized by thickening and folding of the intestinal mucosa and by hyperplasia of the nodes which receive the intestinal lymph drain. It most commonly manifests itself by a severe, more or less periodic diarrhea, and a progressive loss of flesh. Along with these phenomena, there may be observed a pronounced reduction of the milk yield, a staring, dull hair coat, anemia, and terminal cachexia.

The principal lesions are always intestinal. With the exception of the duodenum, the small intestine is usually involved. The cecum frequently participates in the morbid process, and lesions are also encountered in the other parts of the large intestine, especially in the posterior section.

The characteristic lesions, in appearance suggestive of the aspect of the convolutions of the cerebral cortex, as a rule, do not involve the entire gut, but are confined to certain sections. The characteristic corrugation and thickening of the mucous membrane can scarcely be mistaken for changes caused by any other disease. The intestinal wall may become from three to twenty times as thick as in the normal state. The surface of the mucosa is commonly covered by a milky, mucoid exudate. The mesenteric lymph nodes commonly share in the infection and are apt to be found manifestly enlarged.

Johne's disease may occur sporadically or in the form of regular herd enzootics. The infection may remain latent for long periods, and during this time the animals concerned may show no clinical evidence of disturbance. In certain cases of this type the infection was undoubtedly acquired quite early in life. There is no evidence which indicates that affected animals ever recover.

It seems probable that the malady was observed more than one hundred years ago, but it was not until 1895 that Johne and Frothingham described it in a manner which indicated its specific nature. Since that time, paratuberculous enteritis has engaged the attention

of veterinary writers and bacteriologists, and their observations have showed its formidable character. The latter is largely based upon its insidious nature, its ready transmissibility and its capacity for thorough dissemination in exposed herds.

Johne's disease has been reported with increasing frequency from most European countries, from British India, from the United States, and other areas of the world where cattle are being maintained under the conditions imposed by present-day domestication.

It is difficult to discover to what extent the disease is to be reckoned with in this country, but the fact that cases have been reported from many of the states may serve as an indication of a rather wide distribution.

The disease is now generally recognized as a very positive menace to the bovine population in many countries. That it is able to inflict great losses cannot be doubted. In a number of cattle herds in Denmark it was responsible for a loss of 10 per cent of the animals. In certain regions of Switzerland it is estimated that 80 per cent of all cases of chronic intestinal catarrh can be attributed to paratuberculous infection. In a herd enzootic reported by Bugge and Cordsen, not less than 110 animals succumbed to the malady during a period of about 17 years, the losses being principally confined to cattle 1½ to 5 years old.

Susceptible Species.—Cattle show the highest degree of susceptibility to paratuberculous infection, and it is in connection with the bovine species that the disorder has assumed a conspicuous economic importance. The disease has also been encountered in sheep, goats, buffaloes and even in deer. Regular outbreaks in sheep have been recorded, and in these animals the malady appears to be more rapid in its course than it is in cattle.

Cattle have been experimentally infected by intravenous inoculation or by the ingestion of pure cultures of the virus, and similar attempts in sheep and goats also resulted in establishing the disease. The feeding of the intestinal mucosa of a paratuberculous cow, likewise, caused the infection in a hog and a sheep. Such results are, however, not obtained with regularity, and unsuccessful attempts are by no means uncommon.

The artificial infection of the small laboratory animals appears to be even more difficult. Twort and Craig attempted to infect rabbits, fowls and mice by intravenous, intraperitoneal and subcutaneous inoculations, but failed to bring about lesions which in any way resembled those of the disease in cattle.

Andersen, on the other hand, succeeded in infecting 6 rabbits among the 22 treated by intravenous and subcutaneous inoculations. Voluminous and repeated inoculations of the virus into laboratory animals may bring about lesions suggestive of paratuberculosis, but on the whole, such efforts succeed with difficulty in rabbits, and only exceptionally do intraperitoneal injections in rats and mice bring about characteristic intestinal lesions.

The susceptibility of the small animals of the laboratory is such a restricted one that they cannot be successfully used in the study of the disease.

The Virus of Paratuberculosis.—The etiologic factor of paratuberculosis is a small, short, acid-fast, and alcohol-fast bacillus which in many of its characteristics closely resembles *Bacillus tuberculosis.* The organisms can be readily found in the superficial and deeper layers of the affected intestinal mucosa, and in the enlarged mesenteric lymph nodes. In the lesions, they are apt to occur gathered in small clumps or conglomerations.

Most authors have expressed the opinion that *Bacillus paratuberculosis* does not occur in the more remote parts of the body, and attempts to find the organisms in the milk have thus far not been successful. More recently, however, Alexejeff-Goloff found the bacilli in various organs of four affected cows. He also encountered them in a fetus *in utero* and in a newly born calf. He also examined the milk of three of the cows and succeeded in demonstrating the characteristic bacilli.

The organism is rather difficult to isolate, although its capacity for a saprophytic existence is suspected by certain authors.

Modes and Vehicles of Infection.—The specific microbe of paratuberculosis is constantly eliminated from the body of an affected animal with the feces. The latter thoroughly pollute a given environment and are apt to adhere to the hind quarters and udders of cattle suffering from the malady.

All available evidence points toward food and water contaminated in this manner as being the principal vehicle by which the infection is conveyed to healthy stock. This may take place in the stable as well as at pasture. The cakes of dried cow dung scattered about in the pasture as well as puddles of surface water open to fecal contamination, should be regarded as dangerous environmental infection reservoirs. There is ground for the belief that certain permanent pastures may be particularly hazardous for cattle.

The alimentary mode of infection is generally accepted as the principal, if not the only, one to be considered. If other avenues are open for the natural transmission of Johne's disease, they have thus far not been brought to light.

Many observations warrant the conclusion that infective contact may come about very early in life, and that an infected dam and her immediate surroundings may be particularly dangerous for her calf. It was definitely shown that a calf may become infected before the time of weaning, and that in such an animal the disease may remain latent for a long period. The evidence of even intra-uterine infection more recently presented by Alexejeff-Goloff lends support to these observations.

The incubation period of paratuberculosis is always a long one. After the intravenous inoculation of young calves the disease did not manifest itself until after a lapse of from four to eight months. Incubation periods of from six to twelve months are not uncommon, and some authors regard it possible that these periods may be extended to three or even five years.

The introduction of the disease into a healthy herd always follows the acquisition of newly purchased animals. In spite of the suggestion that the specific microbe of Johne's disease may exist in a saprophytic form, there can be no doubt that the disease is scarcely ever transported from place to place except through the agency of an infected animal. The marked latency of the infection renders such a mode of dissemination all the more possible, and hence any animal originating in an infected herd must be deemed a hazard that cannot well be disregarded. There can scarcely be any doubt that in many infected herds animals may be found in which the disease exists without clinical manifestations. That the infection may also be transported by means of infective cow manure is obvious enough considering its intestinal localization.

The rate of the further spread of the disorder once introduced among a group of healthy cattle cannot be foretold with any degree of accuracy. Sometimes new cases develop in rapid succession, and at other times the dissemination may be so slow that the malady remains unsuspected for a long period.

Introduced into new territory, paratuberculosis may fail to attract attention for many years.

Factors Favoring Infection.—The susceptibility of bovine animals to paratuberculosis is not materially influenced by such factors as breed, sex or age. Calves as young as three months of age have been

found to be affected by the malady; in fact, there is a substantial volume of opinion that in many cases the disease is acquired very early in life.

Cattle between the ages of three and six years probably furnish the greatest number of cases. Older animals are found to be affected, even if in this age group the morbidity appears to be less than in the ones which include the younger animals. In the experimental transmission of Johne's disease also, the aged animals are less readily infected by feeding than the young ones.

Season and locality, themselves, have no effect on morbidity, but stables and pastures heavily polluted with fecal matter materially promote the dissemination of the infection if they happen to be occupied by cattle affected with paratuberculous enteritis.

Evidence of a specific resistance to the disease has thus far not been presented in a conclusive manner.

Prophylaxis.—The principles which govern the eradication of bovine tuberculosis are applicable in the prophylaxis of Johne's disease. In this the elimination by slaughter of all diseased animals, as well as of those which can be recognized as being infected, is quite imperative. In the face of the demonstrated possibility of intrauterine infection it would seem advisable to challenge all animals in suspected herds no matter what their age may be, and the calves dropped by recognizedly diseased cows should be kept separated from the other young cattle.

After the removal of the affected animals from the herd, the remaining cattle, old as well as young, should be subjected to diagnostic inoculations of paratuberculin or Johnin, and cattle reacting to the test in a positive manner should also be disposed of in the manner indicated.

In 1927, the Federal Bureau of Animal Industry was authorized by congressional action to proceed with the eradication of the disease in co-operation with the various states of the union, in the same manner as bovine tuberculosis is being dealt with.

These more radical measures should be supplemented by segregation of unexposed calves and young stock away from the older members of the herd. The sooner after the birth of the calves this separation is accomplished the greater will be the prospect of the young animals escaping the infection hazard which may be present.

Scrupulous cleanliness of the stable and its frequent disinfection has a definite place in the scheme of preventing paratuberculosis. Important in this connection is the prompt and thorough removal, as

well as the destruction, of all fecal matter coming from diseased or suspected animals.

Pastures in which the disease had become established should be abandoned by cattle at least for a season, and during this time the surface should be frequently dragged by means of a chain harrow in order to break up the dry or semisolid deposits of cattle manure so that the bacilli present may be more thoroughly exposed to the influences which favor their destruction.

When new stock is to be introduced into a herd the freedom of infection of the former may well be challenged by diagnostic inoculations; animals originating in establishments in which the disease may be present or has actually occurred should always be regarded as a more or less dangerous acquisition.

Experiments having for their purpose the establishment of an artificial immunity to the disease have thus far not yielded results sufficiently clear to warrant application in livestock sanitary practice.

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CHAPTER XVIII

GLANDERS

General Considerations.—Primarily peculiar to the equine species, but not strictly confined to them, glanders has from time immemorial plagued the owners and users of horse stock and has presented a major problem of preventive veterinary medicine. Though less frequent at the present time than during the era preceding the advent of bacteriology and rational preventive medicine, it still must be regarded as the most formidable of horse diseases.

Following the channels of commerce and as an ever-present companion of war, the disease has been scattered over the face of the earth and remains as a more or less constant menace in many countries. Wherever the disease has been completely eradicated, the achievement stands forth as a triumph of sanitary science and practice, of veterinary efficiency and of the enlightenment of the people who are capable of giving support to the needed measures of control.

In the face of the enzootic occurrence of glanders in many parts of the world and of the presence of minor foci of infection in others, the disease continues to demand vigilance on the part of livestock sanitarians in general.

The Virus of Glanders.—The causative micro-organism of glanders, *Bacillus mallei,* is an obligate parasite requiring thus the body of a host animal for its growth and propagation. Outside the animal body, the bacillus is readily destroyed by adverse influences.

Drying destroys the virus, but the time required for its final destruction varies to such a degree in accordance with the nature of the medium in which it happens to be contained, that it cannot well be accurately defined. It probably ranges between 10 and 90 days.

The bacillus is killed by direct solar radiation, but the intensity of its action is greatly modified by the nature of the substances in which the organism is placed, the thickness of the layer of material which the rays must penetrate, the temperature and other factors. Direct sunlight, no doubt, aids in the destruction of virus in certain places, but to place sole reliance on it would not be sound sanitary practice.

The organism shows but slight resistance to heat; an exposure to 55° C. for 10 minutes is sufficient to kill it. At 80° C. the bacilli succumb within half that period.

Placed outside the body of its natural hosts the glanders virus does not survive very long. Contained in clean water the organisms remain alive for about 18 days, in other humid media for from 15 to 30 days and in putrid substances for a somewhat shorter period. In all probability, many factors influence or modify the viability of the virus, and it is not possible to define the periods with accuracy. There is, however, no good reason to believe that virus will remain alive for many months and even years, as has frequently been asserted. They will survive for longer periods when contained in the animal body, where they can multiply, but not in an extra-corporeal situation. All more exact observations tend to show that the period of four months represents the maximum of time that the virus of glanders remains alive outside the animal body. The chemical disinfectants most commonly in use kill the glanders bacillus with promptness.

Host Species.—A number of animal species shows susceptibility to infection by the glanders bacillus, although spontaneous infection is limited to only a few. Among these, the representatives of the equine species are the most prominent, and if the disease now and then occurs in other animals there is always ground to assume that it was communicated by some member of the horse family.

Among the equines the ass and its crosses show the greatest susceptibility, and in them the disease is commonly most virulent. In the horse the chronic types of glanders are more often seen.

After the equines the members of the cat family are most susceptible, and in zoological gardens the feeding of horse meat has occasionally been followed by the development of glanders in tigers and lions. Swine and cattle are not susceptible, and camels, sheep, goats and dogs are quite resistant to the virus although not altogether exempt. Man is quite liable to glanders infection, and human cases of glanders are by no means uncommon.

Modes and Vehicles of Infection.—The fountain-head of glanders infection is the affected equine, the animal showing clinical evidence of the disease in particular, the so-called occult or closed case being a less prolific distributor of virus. The disease is commonly introduced into a stud or stable by newly purchased horse stock. Of especial importance in the spread of glanders are the horses of dealers, carters, itinerant traders, threshing and railway construction outfits, as well as certain centers where equines are apt to be gathered from many

places. Livery and feed stables, lumber camps, fairs, markets and public pastures are apt to be potent foci of dissemination in areas where the disease is more or less enzootic. The chaos of war and the incidental assembling of thousands of horses and mules has always been a highly mischievous factor in the distribution of the infection.

The virus makes its exit from the body of the affected animals with the pus and muco-pus secreted by the ulcers of the skin and the mucosa. It may be contained in the feces, in which case the bacilli eliminated from the air passages were swallowed with food or drink. The urine also has been found to be virulent, but it is questionable that the milk has been proved to serve as a vehicle for the virus. Nasal discharges and the pus set free from broken-down farcy nodules are among the more common vehicles of the organisms.

The infection of healthy animals may come about either by direct or indirect contact. In the former case the infection from horse to horse takes place when the close proximity of the animals permits virulent nasal discharge to be directly conveyed to the body surfaces or mucosa during the acts of coughing and sneezing or when open ulcers of the skin are rubbed against the bodies of other horses.

More prominent as a factor in glanders dissemination is indirect contact. This frequently comes about by the use of common mangers and feed or watering troughs which were previously soiled with the virulent nasal discharges. At pasture, infected horses may contaminate both foliage and drinking water. As a further means of indirect contact mention must be made of harness (bridles especially), saddles, blankets and grooming utensils.

Glanders bacilli may enter the body through various portals, among which the alimentary tract, the upper air passages and the abraded skin are to be considered as the most common ones. To a less extent is the virus apt to enter through the conjunctiva or through the mucosa of the genito-urinary tract. Infection of the fetus *in utero* has been observed, but its occurrence is quite exceptional.

The entrance of the virus through the alimentary canal by means of contaminated food and water is without doubt the most common mode of infection, and although the frequent involvement of the nasal mucosa may point to a special vulnerability of that structure, there is reason to believe that this is ordinarily more often induced by metastasis than by surface exposure to the virus.

As long as the skin remains intact, it serves as an effective barrier to the virus, but the latter may readily enter through abrasions.

Infection by aspiration into the upper air passages does not appear

to be as common as ordinarily believed, but this method of penetration may bring about alimentary infection when the virus finds its way into the pharynx.

Factors Favoring Infection.—Aside from conditions and circumstances which facilitate the spread of infection from place to place, the susceptibility of the animals exposed is modified by predisposing influences. Various depressing factors may increase the liability to glanders infection as well as the severity of its action after this has taken place. In the premallein days it was a common practice to subject suspected horses to the depressing action of a severe cathartic in order to enhance the development of clinical evidence permitting a definite diagnosis.

Under-nourishment, over-work, debilitating diseases all tend to increase the susceptibility of horses to the disease and aid in bringing about its more virulent forms. An attack of influenza has frequently become responsible for the development of acute glanders in previously occult cases.

The susceptibility to glanders often shows a tendency to decrease with age; younger horses commonly will become more readily infected than old ones and are as a general rule more apt to show the acute forms of the disease.

Unhygienic stable conditions and unsanitary feeding and watering equipment likewise tend to promote the spread of infection as well as to add to the infection hazard of the animals living in such an environment.

Immunity.—Because infected animals present well-marked allergic or immunity reactions to specific glanders antigens, the belief is warranted that the protective forces of the susceptible animal may become increased or mobilized by immunization methods. However, it has thus far not been possible to develop an immunization technique which can be regarded as practical or safe. It is even doubtful that the relatively slight susceptibility to glanders shown by horses belonging to certain sections can be ascribed to a natural resistance to the disease based on a certain degree of immunity. In the light of present knowledge, immunity to glanders is as yet without hygienic importance.

Prophylaxis.—As in many transmissible diseases, the primary objects in glanders prevention are the protection of healthy or noninfected animals and the elimination of the ones already affected with the disease. The presence of the latter in a given area determines the need of placing certain barriers around the former.

Erection of Barriers.—In the face of existing glanders infection,

the most essential measure in the protection of non-infected studs or stables is the challenge by either mallein or serologic test of any new equine to be admitted. Even when the first test applied yields negative results, it is well to repeat it after six or eight weeks unless there is sound reason to believe that the animals involved came from sources with an established record of freedom of infection. The purchase of old horses coming from cities or distant sections must either be avoided or especially safeguarded in the manner indicated.

In the areas in which glanders is prevalent, healthy horse stock should not be exposed to infection risks which are apt to exist in public stables or pastures, and roadside watering troughs promiscuously used by other horses should be avoided. When the disease is present in a community, teamsters or drivers should be provided with special pails for watering their horses while at work or en route. Contact with other horses should be avoided so far as this can be carried out, and interchanges of harness, saddles, blankets and grooming utensils should also be prevented. The periodic application of mallein or serologic tests to healthy horses in infected areas can be recommended as additional safeguards.

Hygienic Environment.—The guarding against contact with infected animals must be regarded as the principal measure to be taken in the protection of healthy horses, but the maintenance of a sanitary environment and stable management are also important factors. Proper stable construction with regard to cleanliness, lighting and ventilation are not without a definite influence in the prevention of the disease. Clean practices of feeding and watering are important and in stables and markets with a transient horse population especial attention should be given to feeding and watering utensils supplementing scrupulous cleanliness with frequent disinfections.

In infected districts it is doubtful that even with the precautions mentioned, public stables, markets or pastures can be made into safe environments by sanitary measures alone.

Elimination of Infection Sources.—Although private efforts intelligently made are often effective to prevent the introduction of glanders into clean studs and stables, the disease has scarcely ever been adequately suppressed or eradicated in any area without the exercise of the police power vested in government.

This fact received early recognition, and in many states and provinces the first attempts at livestock sanitation as a public activity were solely directed against glanders. Even those initial efforts, however seriously undertaken, were not altogether successful until they

were strengthened by the practice of reimbursing, from public funds especially set aside for the purpose, the owners for animals condemned. Then, and then, only could substantial progress be made, because without this practice the necessary co-operation by horse owners could not be secured.

The effective suppression of glanders is above all dependent on the eradication of infection sources, and as such the equines which show clinical evidence of the disease, as well as the ones showing positive reactions to the mallein or serologic tests, figure most prominently. If glanders is to be successfully eradicated, no distinction should be made between clinical cases and reactors, even if the latter may not always be infection spreaders or their ultimate recovery cannot always be excluded.

With the destruction of all reactors, as potential disseminators of the glanders virus, the problem of so-called "missed cases" disappears, and its execution becomes a matter of public economy when consideration is given to the financial losses occasioned by the disease and the high cost associated with its suppression. The sparing of reactors has on many occasions been proved to be a costly mistake.

As the most prolific spreaders of infection, the clinical cases should at once be destroyed and disposed of either by deep burial or complete incineration. All contact animals and especially those belonging to the same stud, stable or owner must then be subjected to a mallein or serologic test, and the ones showing a positive reaction should be dealt with in a manner similar to that which disposed of the clinical cases. The more rigidly this plan is carried through, the less the eradication costs will be in the end.

Doubtful reactors should be segregated until another diagnostic test can be undertaken some four or five weeks after the first one. Horses and mules which failed to react to the first test may then also be retested in order to avoid the possibility of missing a recent infection.

As long as the stable or its equipment has not been disinfected, the apparently infection-free animals should be removed to other quarters, and in this connection a cattle stable can be used to advantage and with entire safety. The cleaning and disinfection of the stable, eating and drinking utensils, harness and such objects as nosebags, blankets, curry combs, brushes and other pieces of stable equipment, should, however, not be delayed and must be done in a most thorough manner.

After the elimination of clinical cases and reacting animals, the ones remaining should be kept under observation and by suitable quarantine measures be prevented from coming in direct or indirect contact with other horse stock.

Another test by mallein or by complement fixation may be made four months after the elimination of the last clinical case or reactor, and in the event of negative reactions only having been obtained, further restrictions can then be safely removed. There can, however, be no objection to tests between the initial and the final one, but the quarantine restrictions should not be suspended until four months have elapsed between the removal of infected animals and stable disinfection and the final negative test.

Of the utmost importance in the control of glanders is the tracing of the infection. Not only should an attempt be made to discover the source from which a given outbreak may have derived its initial infection, but it is equally essential to know the studs or stables which were exposed to the disease by the animals involved in the outbreak under actual observation. With the discovery of the former an important source of mischief may be closed, and by attention to the latter new outbreaks may be prevented at a time when they can be controlled at a minimum of public or private expense.

In areas in which glanders is at all prevalent, horse markets and other establishments where large numbers of horses are being assembled should be kept under sanitary supervision, and this may be made to include the application of diagnostic tests before the animals can be admitted. The latter measure has also been proved to be helpful in the protection of glanders-free districts against the infection carried by horses in transit or those belonging to itinerant traders, to contacting firms or to similar organizations.

In cities, which not uncommonly are centers of infection, the closing of public watering troughs may be a necessary step, and in such cases the watering by means of specially carried buckets should be made compulsory.

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CHAPTER XIX

STRANGLES

THE disorder which is best known by the name of strangles or colt distemper is an acute, febrile, communicable disease of the solipeds marked by inflammation of the nasal, pharyngeal and laryngeal mucosa and by suppuration of the lymph nodes of the region involved.

Strangles is distributed over the entire world with the possible exception of Iceland and is common wherever there is an equine population sufficient to sustain it. In the popular mind, the disease is as inevitable to young horses as measles is to children, and indeed very few horses escape the infection during the first four or five years of life.

The disease is apt to be prevalent where colts and young horses are being maintained in numbers. In such establishments as large studs or remount stations it is apt to persist in an enzootic form or to occur as formidable epizootics; among sparser equine populations sporadic cases are more commonly seen.

On the whole, colt distemper is a formidable affection more because of its wide distribution than on account of a high mortality rate. The latter is low and in given outbreaks it usually ranges from zero to about 3.5 per cent. In the more typical, benign cases, the disease causes an incapacity for work lasting between ten and twenty days. It is apt to cause impairment in health on account of such complications as laryngeal hemiplegia or by reason of articular or osseous defects caused by metastasis. To this must be added a certain tendency of focal infection in various regions of the body.

The Virus of Strangles.—The etiologic factor of strangles is the *Streptococcus equi,* a specific entity among the pyogenic streptococci. Like other pus-producing microbes the strangles streptococcus is widely distributed, and although a saprophytic existence must be given consideration, the organism is usually associated with horse stock and with the environment in which such animals are being maintained.

The strangles coccus is apt to present itself in the form of strains

differing considerably in their pathogenic qualities, which range from complete avirulence to a marked capacity for pathogenicity.

The organisms are most numerous in the discharges of the affected mucous membranes and, above all, in the pus formed in the suppurating foci. They do not usually occur in the circulatory blood, but there can be no doubt that the latter occasionally serves as the vehicle by which their dissemination through the body is made possible.

The resistance of the strangles streptococci to external influences is a not inconsiderable one, and, no doubt, this accounts for their tendency to cling to stables and other parts belonging to the environment. The organisms contained in dried pus or blood are apt to remain viable and virulent for weeks, but after a period of about 3 weeks a gradual attenuation is likely to take place.

The virulence is subject to the action of heat and is usually lost after a 10 minutes' exposure to a temperature of 60° C. If this exposure is prolonged to 1 hour the cocci are killed. An exposure to 80° C. kills them in 15 minutes; the temperature of boiling water disposes of them in a few minutes.

A more or less prolonged exposure in a putrefactive medium is fatal, and the organisms are quite sensitive to solar radiation, an 8-hour exposure being sufficient to deprive them of their viability.

The resistance of the strangles streptococci to the common disinfectants is a rather feeble one. An exposure for from 15 to 30 minutes to either a 1 per cent phenol solution or a 2 per cent solution of the saponified cresols is usually sufficient to destroy them. A slightly acidulated sublimate solution (1:2000) kills the germs in less than 5 minutes.

Susceptible Species.—The solipeds are the only animals susceptible to the natural strangles infection. Of these, the horse is the most liable; the mule shows a less degree of susceptibility and the ass is still more resistant.

Mice are also susceptible to strangles infection and constitute the species most suitable for experimental purposes. Rabbits and cavias are more resistant; they yield only to massive intravenous or intraperitoneal injections with young cultures of the streptococci.

Modes and Vehicles of Infection.—Affected horses are always the chief source of strangles infection, but certain animals without being manifestly ill may, nevertheless, serve as spreaders. The dissemination of the virus generally takes place by means of the purulent discharge from the involved mucosa or as a result of the spontaneous rupture of the abscesses. These substances, by the pollution of the

stable and the contamination of food and water, play an important part in keeping the infection more or less stationary in certain establishments.

In stables, more especially those which are poorly ventilated or otherwise unsanitary, the air may serve as a vehicle for the virus. The droplets of discharge expelled during fits of coughing and sneezing are apt to remain suspended for a time and may thus be inhaled directly by other animals, or they eventually settle in mangers or watering troughs to be taken in as occasion presents itself.

The mucosa of the respiratory and alimentary tracts furnish the most common port of entrance for the streptococci of strangles. Cases of transmission during copulation have been observed, and the introduction of the virus through wounds is by no means an uncommon occurrence. The castration of colts among whom strangles is present is always a hazardous undertaking because of the possibility of such sequelae as streptococcic peritonitis or pyemia. There is some evidence which shows that the mammary gland may also serve as a port of entrance for the virus.

The incubation period of strangles ranges between four and eight days.

In general, the spread of strangles is made certain by commercial transactions and the assembling of horses in public stables. The disease is particularly apt to be found among the horses in oversea transit, and troop horses are almost inevitably infected on such occasions unless extraordinary precautions are taken.

Infected horses are the common agent by which the disease is carried from place to place, but dissemination may also come about by means of water, dust, food remnants, straw and soiled objects such as pails, blankets, harness and grooming utensils. Persons, dogs or small animals may serve as vehicles.

Factors Favoring Infection.—The influence of age on the susceptibility of strangles is always in evidence. Colts or young horses between the ages of two and five years furnish the greater number of cases, although older horses, even very old ones, cannot always be relied on as being resistant to the disease.

Horses which sustain a previous attack of strangles are more resistant or may even have acquired a high degree of immunity. This immunity, however, is commonly only a partial or incomplete one, and the same animal may become affected several times at more or less extended intervals.

Certain predisposing factors favor the infection; among these,

mention must be made of constitutional depression by chilling, previous catarrhal diseases, inclemencies of weather and the hardships incidental to long-distance transportation. Continued stabling exercises an unfavorable influence not only on individual susceptibility but on the severity of the infection and the rapidity of its dissemination as well. Even without sanitary faults of stables, strangles is always somewhat of an indoor disease.

Prophylaxis.—The marked susceptibility of young horses to strangles and the common occurrence of the disease as a direct consequence have combined to make prophylaxis almost an illusory undertaking. The difficulty is further increased by the fact that the immunity engendered by a previous attack is apt to be transitory and although it may have a considerable protective value to the individual animal, it does not prevent the virus from finding a suitable soil for its propagation.

It is to be foreseen that wherever a considerable number of young horses are being maintained a more or less permanent focus of infection will be established from which the disease is being continually conveyed to other centers of equine population or to the smaller units commonly found on farms. This unfavorable prospect for a successful prevention of the disease may, however, be improved by the application of certain prophylactic measures which, likewise, may rob the infection of some of its more damaging characters.

Sanitary Measures.—The most essential of all measures designed to prevent strangles is the elimination of all possible chances of contact. Public stables should be avoided by the more susceptible animals, and such possibilities of indirect contact as supplied by public watering troughs, contaminated feed, bedding and accoutrements should be carefully removed.

New arrivals at remount stations and other disease-free establishments requiring the introduction of young horse stock should be kept in segregation for at least two weeks. Horses assembled for transmarine transportation should be kept ashore until the absence of strangles is well established or until the latter has run its course, if such is at all possible.

In the event of stable outbreaks, the horses should be removed to pastures or paddocks if the season permits such action. The affected and healthy animals should be separated and divided in as many small lots as possible. If stabling is imperative, the utmost cleanliness must prevail; especial attention should be paid to the improvement of the

ventilation and to the frequent disinfection of mangers, troughs and the utensils with which the animals are in close contact.

Abscesses should be promptly evacuated and the pus carefully collected for destruction by fire instead of permitting this exquisite vehicle of virus to be scattered about.

In horse units where the disease prevails, the animals should not be subjected to any surgical procedure such as castration for at least one month after the complete recovery or the elimination of the last case.

The value of stable disinfection may be somewhat dubious, but it should, nevertheless, be practiced as a means to promote general cleanliness.

Immunization.—In spite of the commonly observed evanescence of the immunity engendered by a previous attack of the disease, various attempts have been made to establish resistance by artificial means. Serum obtained from carefully hyperimmunized horses has frequently been used in order to confer a passive immunity. Preference is given to polyvalent sera, but the reported results are quite contradictory. Inasmuch as some favorable results have been obtained, there is warrant for making use of serum injections in exposed animals, although one should not be too sanguine in one's expectations.

The results following the use of vaccines in the form of cultures killed by heat or by chemical action, or by bacterial extracts are likewise contradictory.

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CHAPTER XX

JOINT-ILL OF FOALS

JOINT-ILL, or pyosepticemia, is an infectious disease peculiar to the new-born and early juvenile phases of life. It is characterized by a septic omphalophlebitis, by purulent arthritis and by pyemic manifestations.

As the malady occurs in foals, it has been observed for many decades in the various parts of the world where the breeding of horses is included in the prevailing type of animal husbandry. The veterinary literature of the previous and present centuries is frequently occupied with joint-ill of foals and also brings to light its presence in the young of other domesticated animal species.

The disease is commonly initiated by a marked inflammatory, painful swelling of the umbilical region, fluctuating and yielding a thick, creamy pus when opened. This may, or may not, be preceded by a high body temperature, which, however, is usually observed when joint involvement and septic intoxication become apparent. Occasionally, the latter manifestations declare themselves without initial lesions of the umbilicus.

The infected foal loses its appetite, becomes lame and is apt to persist in a recumbent position. The arthritis is often a multiple one; the affected joints are swollen and tender, and frequently show a periarticular edema. The infection may have its site in any one, or several, of the articulations. The stifle, hock and elbow are, on the whole, most frequently involved.

In the more acute septicemic forms of the disorder, occasionally accompanied by diarrhea and rapid exhaustion, a fatal termination may come about in two to four days. Most of the cases are less acute and may even show a tendency toward a chronic course. In such a case the animals lose flesh to the extent of a profound marasmus, become crippled and may linger as long as three months and then succumb to a terminal pneumonia.

In foals, the case mortality ranges between 50 and 90 per cent, and in part of the survivors a locomotor impairment remains as a

permanent defect. In the young of other species the mortality is generally less severe, although in their case also the disorder is apt to leave many defectives.

The morbid changes revealed by autopsy are in accord with the clinical manifestations. The region of the navel is inflamed and purulent, and abscess formation is commonly observed in these parts. The umbilical vessels contain softened, broken-down thrombi, and hepatic abscesses may be revealed. Metastatic abscesses in other parts of the body are frequently seen, confirming the pyemic character of the disease.

The affected joints are inflamed and thickened, and their synovial sacs enclose a cloudy, purulent synovia. In the more chronic cases the articular cartilages are damaged and the heads of the bones denuded. Anchylosis may be observed. Tendon sheaths may be found to be participating in the general infection.

Affected Species.—Joint-ill is particularly prone to occur in foals, but is also observed in calves with a certain degree of frequency. It is more rarely seen in lambs and pigs, although among these animals, also, regular outbreaks may occasionally be witnessed.

The Microbic Causes of Joint-ill.—Several distinct microbic species must be reckoned with in the etiology of pyosepticemia. Strains of streptococci (*S. pyogenes, S. equi*), *Bacillus viscosum equi, Bacillus coli commune, Bacillus abortus equi, Bacillus paratyphi, Staphylococcus aureus, Diplococci* [resembling *D. lanceolatus*] and other microbic forms have been identified with the disease.

Of these, diplostreptococcus infections show the highest incidence, but those of *Bacillus viscosum equi, Bacillus coli commune,* and *Bacillus abortus equi* are by no means of rare occurrence. Local influences appear to play a part in their relative frequency as etiologic factors of joint-ill.

Modes and Vehicles of Infection.—Although some of the microbic species etiologically associated with joint-ill are, no doubt, more or less ubiquitous in stables and other enclosures inhabited by livestock, or as relatively harmless parasites of the animals themselves, the ones more often found in connection with the disease are eliminated by affected animals with exudates of the inflamed umbilicus, with the pus evacuated from joints or abscesses or with the body wastes.

In the cases in which *Bacillus abortus equi* plays a part in etiology, the micro-organisms may be present in the uterus, and under such circumstances intra-uterine infection is apt to have taken place.

That such a mode of infection may also be observed when other bacteria play a part as causes cannot be denied. A number of authors insist that prenatal infection is the more common mode of transmission; others maintain that it is of exceptional occurrence. It seems probable that such differences of opinion, to a degree, arise from the fact that the specific nature of the organisms associated with the disorder is not always given sufficient consideration. In districts where the equine abortion bacillus is a common pathogen, prenatal infection is apt to occur more regularly than in those where streptococcic navel infections are prevalent.

In the larger number of cases of pyosepticemia, the infection is of extra-uterine origin; the umbilicus must be regarded as the more common port by which the microbic agents enter the body.

In streptococcic pyosepticemia, commonly preceded by manifest inflammatory changes of the umbilicus and adjacent parts, the extra-uterine origin of the infection can be safely accepted. Such an infection may take place either within or without the genital passage.

When colon or paratyphus organisms are the etiologic factors, enterogenous infection cannot readily be excluded even if there is not a marked volume of evidence to show that infection *per os* is of frequent occurrence.

Bacillus viscosum equi is, with a few possible exceptions, always introduced via the umbilicus. Experimentally acquired evidence shows that new-born foals cannot be infected with this organism by the administration of large amounts of culture by mouth, whereas the injection of such cultural material into the umbilical vessels or into the jugular vein is apt to be followed by the development of pyosepticemia in its characteristic form.

In umbilical infection, the exposed, torn tissues of the stump of the cord and the umbilical vessels supply the portals of entrance as well as the avenues of invasion for the micro-organisms, which eventually results in the infection of the more remote structures of the body.

The bacteria concerned are introduced through contact with the contaminated maternal body, and with the bedding and other environmental objects polluted by it. The dirty hands of attendants may likewise serve as vehicles for the virus.

The introduction of the virus is followed by inflammatory reactions in the walls of the umbilical blood vessels, by the softening of the thrombi present in the latter and by the microbic invasion of the adjacent parts. The micro-organisms are transported by the blood

stream to the liver, and after gaining the general circulation they are rapidly disseminated throughout the body.

They find a *locus minoris resistantiae* in the various articulations, and focal infections of the liver, lungs, kidneys and other organs are by no means of rare occurrence.

Factors Favoring Infection.—Among the influences which favor the development of joint-ill, the one exercised by age overshadows all others in importance. Seasonal, climatic or topographic factors do not appear to have a marked influence on pyosepticemia morbidity.

Joint-ill is a disorder pre-eminently associated with the new-born and early juvenile periods of life. Like other infectious maladies of young animals, it asserts itself before the organism has become endowed with the qualities which enable it, at a later period, to withstand microbic invasion.

The polybacterial etiology of the diseases peculiar to the early stages of post-natal life in itself tends to show that at that period the animal organism is particularly vulnerable to assaults by pathogenic microbes or even by bacteria which are only potentially so.

Any of these bacterial species which may find in the animal body an optimum medium of growth and development is apt to give rise to morbid disturbances. The clinical and patho-anatomic phenomena which follow the invasion are, to a large extent, associated with organs and parts where a special *locus minoris resistantiae* exists. In many cases, the entire body may be regarded as such.

Another factor which favors joint-ill infection is the insalubrity of the environment in which the highly vulnerable young animals may be placed. Stables contaminated by the microbic species involved or inhabited by adult animals in or on the bodies of which they occur as saprophytes or as harmless parasites, may play a part as factors favoring infection.

Prophylaxis.—Because of the part played by the umbilicus as a portal by which the various microbic causes of joint-ill enter the body, it is obvious that obstetrical hygiene is of manifest prophylactic value. This is especially true in stables or breeding establishments where the disorder had previously occurred.

The external genitals and adjacent parts of the mare should be carefully cleansed and disinfected prior to parturition. With the completion of the latter, the foal should be received upon a clean sheet and all contacts with environmental objects must be carefully avoided.

The cord is to be ligated with sterile material and aseptically severed. This completed, the stump of the cord, as well as the parts adjoining, should be covered with an iodine solution (tincture iodi 1 part, glycerine 3 parts). This application may be repeated from time to time until the navel has become cicatrized.

The foal and its dam should be placed in clean quarters, preference being given to an environment in which the malady has not occurred for a considerable period.

Immunization.—The preventive treatment of exposed foals by means of anti-sera, vaccines and other substances has not resulted in uniformly favorable results. Opinions regarding the value of such procedures range between endorsement and condemnation. The polymicrobic nature of the malady may be largely responsible for the variable results, and a slow development of resistance in the foals may be another factor in the failure to bring about prompt and adequate protection.

Forsell, who assumed that the infection of joint-ill is of intrauterine origin, proposed that the sick or endangered foals receive liberal injections of the blood serum of the dam. As the disorder was shown to be largely due to post-natal infection, the method was, by some authors, rejected as an illogical one. Although this viewpoint may be correct, nevertheless, a not inconsiderable volume of data has accumulated to indicate that the injection of the dam's blood had a rather marked value in the prophylaxis of the disorder.

Whether due to specific antibodies or to other undetermined protective substances, the experience acquired with Forsell's procedure tends to show that the dam's blood confers on many foals qualities which enable them to survive in the face of hazardous exposures.

In stables where the infection danger is particularly to be feared, the foals may be injected intravenously, or subcutaneously, quite soon after their birth. About 200 c.c. of the dam's blood is collected in a vessel containing 20 c.c. of a 2 per cent solution of sodium citrate, to prevent clotting, and the mixture injected immediately.

Ordinarily the blood injection can be postponed for 8 to 10 days. During this period the temperature of the foals should be subjected to daily control. An increase of the temperature must be accepted as an indication that the treatment should not be further delayed. In such a case, and in the one pertaining to exposed colts 10 to 12 days old, from 400 to 500 c.c. of the dam's defibrinated blood or blood serum are to be injected. This treatment may require to be repeated in the event of further temperature reactions.

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CHAPTER XXI

BOVINE MASTITIS

The highly developed mammary organ of dairy cows is particularly liable to a number of injuries and diseases which are less common in the types of cattle in which selective breeding has not been so intensely directed toward udder refinement and functional capacity. The greater part of these diseases are of microbic origin, and some of them are of livestock sanitary importance or are rapidly becoming so because of their increased incidence and the damage they are capable of inflicting.

Streptococcic mastitis, perhaps the more common and most formidable of udder infections, is in many herds a source of a material reduction of the milk yield, and, in addition, the disease brings many otherwise desirable animals to the block. This chronic, insidious and readily transmissible disease usually results in serious, permanent udder impairment.

In certain countries, streptococcic mastitis has become widely distributed. Klimmer estimates that in Central Europe from 10 to 20 per cent of the cows are affected by it. The losses caused by udder diseases in Austria are estimated at more than six million gallons of milk annually, or about 20 per cent of the milk shortage to be covered by importation. On the whole, mammary infection constitutes a most serious incubus on the dairy industry, and in many areas it ranks with abortion as one of the most potent sources of financial loss.

Minett reports the examination for streptococci made of 850 milking cows belonging to 16 herds in Great Britain; not less than 333 of these cows were found to be affected. The incidence in each herd ranged between 11 and 65 per cent. In this country, the incidence of udder infection is probably not so high as in some of the European countries, but evidence is not lacking that here, also, the more damaging mammary diseases are on the increase.

They may present themselves as isolated cases or occur in the form of herd infections or outbreaks. Especially in the case of streptococcic mastitis, the disease has deeply infiltrated into a given herd

before severe udder impairment brings an owner to realize that he is confronted with a problem of serious import.

Therapeutic measures usually bring unsatisfactory results, and although in certain forms of mastitis recovery may eventually come about, there is no conclusive evidence that any treatment can be credited with any material influence. This is especially true of those mammary infections which, by their ready transmissibility, are most apt to place an entire herd in jeopardy. Foremost among these is the form caused by specific streptococci. This type of mastitis is not only perhaps the most common but also the most damaging. The additional fact that certain streptococcic throat infections of man were traced to the consumption of raw milk of infected cows has given this problem a public-health aspect as well as a livestock sanitary one.

Etiologic Factors.—Although clinically and pathologically several forms of mastitis are recognized, their etiology is by no means always identical. Certain microbic species are certainly capable of giving rise to more or less characteristic clinical and pathological features, but in general the various mastites are of polybacterial origin.

Almost any microbic invasion of the udder may result in more or less severe inflammatory reactions. Some of these bacterial species widely distributed in nature as saphrophytes find in the mammary gland a suitable condition for growth and reproduction. Capable of adaptation, they may acquire an exalted virulence and thus become formidable as the cause of transmissible disease.

Organisms of the colon-typhus group, *Staphylococci, Diplococci, Streptococci, Bacillus pyogenes, Bacillus pyocyaneus,* abortion bacilli and many other microbic species may be found to be etiologically associated either with the sporadic forms of mastitis or with those occurring as enzootic herd infections and regular outbreaks.

Among the micro-organisms which may have an etiologic relationship to udder disease, some are more prominently identified. Such are *Bacillus coli commune* (*Bact. phlegmasiae uberis* Kitt) and the mastitis streptococcus (*Streptococcus agalactiae contagiosa* Kitt). The latter, as the cause of streptococcic mastitis, is of the greater economic importance. Not only is this form of mastitis the one most commonly encountered, but owing to its ready transmissibility and the havoc it produces in the mammary structures, it has gradually assumed the status of a more or less pressing problem in livestock sanitary practice. To this must be added its public-health aspect, in connection with its possible relation to septic angina in humans.

Modes and Vehicles of Infection.—Three avenues are open by

which infective microbes may gain entrance to the udder. The blood stream, the lymph channels (wound infection) and the teat canal and milk ducts by which the mammary apparatus drains itself, may all serve in the admission and dissemination of the infective organisms. The udder infections which may be of special livestock sanitary concern are probably introduced exclusively through the teat canal and conveyed to the mammary parenchyma by way of the lactiferous ducts.

The causative organisms leave the infected mammae by the same route. They may be variously conveyed to healthy udders. The hands of the milkers and the cups of the milking machines are particularly potent in the distribution of the streptococci of mastitis in a given herd. In addition, the practice of draining infected quarters on the ground, or on the stable floor, is apt to supply a very potent environmental infection source. Teats coming in contact with virulent materials so deposited, especially in the presence of moisture, commonly furnish the port of entrance to the virus.

Another infection source is to be found in an infected genital tract. A uterine discharge readily contaminates the entire area between the vulva and the teats of the posterior quarters and may, in the case of a profuse discharge, or during rainy weather, bring a continuous stream of infective liquid to the teat's orifice.

Organisms, and especially streptococci, introduced into the teat canal and polluting the moist walls or contents of the milk cistern, soon begin to exert their pathogenic action. In a marked degree this action is dependent on the splitting of the lactose present and on the formation of toxines.

The period of incubation after such a natural infection may be exceedingly short, a few hours only. After experimental infection the first manifestations of inflammatory reaction declared themselves two hours after the contact.

Factors Favoring Infection.—To what extent mammary infection may be dependent upon such predisposing factors as weather, feed, drinking water, and others, is difficult to ascertain. Chilling and the occupation of drafty stables have long been recognized as playing a part in the etiology of mastitis. In the light of our present knowledge of infection, these influences do not appear to be as potent as they were regarded to be during a previous era. It is, however, not inconceivable that any weather conditions which keep infective body discharges from drying, or which drench the parts involved with rain water may, after all, tend to facilitate udder infection.

That the disease may take its origin from the filth from the perineal region, may in fact be thus promoted, is suggested by the fact that the hind quarters of the udder, more frequently exposed to this type of contamination, show a mastitis incidence twice as high as the front quarters.

A more potent predisposing factor is inadequate, unskilled and incomplete milking. This leaves the milk cistern distended with milk which, impinging on the internal opening of the teat canal, tends to render the latter patulous, more open to the microbic invasion. Leaving the teat moist will further the entrance, as in such a case there is a continuous humid culture medium extending inward.

The most potent of all factors which tend to increase the mastitis hazard is the functional activity of the udder itself. Most cases of mastitis arise within a brief period after parturition, and the more productive, the more developed the udder, the greater the probability of its becoming involved in mastitis. The more refined the breed of cattle in respect to milking qualities, the more are the udders vulnerable to microbic invasion. Analogously, the life period of greatest mammary development is also the one during which mastitis incidence is the highest. This tends to explain why its morbidity increases up to the ages of five to seven years, when apparently the chances of mammary infection are the highest.

That unhygienic stable conditions promote the occurrence and propagation of mastitis is obvious, and that filthy milking practices have much to do with bringing about udder infections and their transmission can be readily understood if the nature of the virus and its modes of diffusion are given consideration.

Traumatism of the udder is always a factor which increases the mastitis risk; in this connection the use of milking tubes, teat dilators and similar devices must also be mentioned. No other organ is more vulnerable to infection than the well-developed udder of the better dairy breeds. To a microbic invasion the mammary structures offer but little resistance, and the introduction of an instrument without surgical asepsis is always apt to result in serious consequences.

Prophylaxis.—Because all forms of mastitis are of microbic origin, all cases of the disorder should be regarded as a potential herd menace. No doubt, there are udder infections of a benign or transitory character, but even if a given case is recognized as such it should be handled with due regard to the possibility of transmission to other cows.

Herd managers are still apt to look upon mammary inflammations

as being of a sporadic nature and can often supply the most plausible reasons for such an opinion. Only after a number of udders have become defective or completely impaired does it occur to them that they may be confronted with a more serious problem. Even then, feed, weather or season are often regarded to be the fundamental cause, and not uncommonly the specific microbic origin of the mischief is the one least suspected. For this reason alone, the proper instruction of the personnel of an establishment is perhaps the most effective of all measures of prophylaxis.

Every udder disturbance of an inflammatory nature should be challenged as to its character, and any abnormality of the milk should be given attention. Newly purchased cows in particular should be carefully observed, and the appearance in the milk of mucous flakes, casein clots or blood should be the occasion for a microscopic or bacteriologic examination. The cows concerned should always be milked last and preferably by hand.

In all herds, whether free from udder disease or not, the milkers should be clean, carefully washing their hands after each separate milking. The cups of the milking machine should likewise be subjected to a thorough sterilization either by the use of some suitable disinfectant or by scalding, before being applied to the teats of the next cows to be milked. A cup constructed in such a manner that it does not admit of such cleansing should be rejected.

The milking should always be thorough and complete, and the cleansing and drying of the teats after each milking must always be regarded as a measure of considerable hygienic value. The cleaning of the perineal region and the escutcheon also tends to safeguard the udder, especially in the case of animals showing a vaginal discharge or when fecal pollution of the parts is present.

The practice of moistening the teats prior to milking must not be tolerated. If something of the sort is necessary, some clean, bland oil or fat should be used.

In herds containing cows suffering from mastitis, it should be a practice to milk such animals last of all, preference to be given to hand milking. The milk obtained from the affected quarters is to be collected in separate vessels and must either be destroyed after mixing it with some active disinfectant or be boiled before its use as a food for other livestock.

In such herds, a sample of the milk of each quarter of every cow should be collected in a separate container and the sediment subjected to a bacteriologic examination to determine all possible infection

sources. Such examinations should be frequently repeated until all infection sources have been eliminated.

The procedure is of particular value in the face of streptococcic mastitis. Apparently recovered cases always tend to remain the carriers and spreaders of the infection, and in exposed herds there are apt to be found apparently normal udders in which the specific streptococci can, nevertheless, be found.

Whenever possible at all, cows with infected udders should be eliminated from the herd or stable. The recognition of the first case of streptococcic mastitis, its prompt isolation and disposal by slaughter is a most important step in the prevention of future disaster.

This radical procedure is apt to bring the best results in prophylaxis. If it is not applicable, makeshift methods may be resorted to. Zschokke recommended the discontinuation of the milking of the affected quarters altogether in order to prevent the further exit of infective material. Weber reported success from the injection of 200 cc. of a 0.75 per cent solution of silver nitrate, after the thorough draining of the quarters involved. No doubt the drying of affected quarters will diminish the infection chances in a given herd and may tend to reduce the hazard of a more general distribution of streptococci, but there still remains a potential danger associated with the continued presence of the specific virus.

Protective inoculations with streptococcus vaccines have been recommended. Some authors reported satisfactory results whereas others were less fortunate in their experience. The evidence pertaining to the value of immunizing procedures against streptococci mastitis is quite contradictory and rather tends to show that at this time the solution of the problem by this method is still a matter for future consummation.

The elimination of infected udders after bacteriologic examination, scrupulous cleanliness in milking technique and hygienic methods of stable management remain as the best, perhaps the only, means of defense.

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CHAPTER XXII

THE ABORTIFACIENT INFECTIONS

In not a few of the microbic diseases of animals the involvement of the contents of the pregnant uterus and the subsequent casting off of the fetus is a more or less frequent accompaniment of the general morbid process, but there are other specific infections with a particular affinity for fetal structures which so regularly interfere with normal gestation that under the name of contagious or infectious abortion they have come to constitute a very definite and important problem in livestock sanitation.

There is as yet no certainty in regard to the number of microbic species which may be implicated in the ultimate production of abortion. There is, however, certainty regarding the fact that in cattle and swine the *Bacillus abortus* of Bang and in the horse the *Bacillus abortio equi* are responsible for such a preponderating fraction of the abortions occurring among these animals that those organisms and the pathologic processes to which they give rise have acquired an importance which far transcends a mere academic interest. That the other micro-organisms which from time to time have been found in apparently incriminating positions may likewise play a part cannot be denied with any degree of certainty or finality, but so far as the subject is viewed in the light of present knowledge, the specific infections mentioned constitute the heart of the problem. They are the ones against which preventive efforts can and must be undertaken at this time.

Abortifacient Infection of Cattle.—Conventionally and most widely known as bovine infectious or contagious abortion, the disease presents certain features which for the greater part must be given consideration before its management can be contemplated.

The causative factor of the infection is the abortion bacillus of Bang. It has not been shown that this organism is regularly pathogenic to adult or adolescent cattle. On the other hand, its capacity for bringing about morbid changes in the tissues of the fetus, more particularly in the deciduous ones, is quite formidable. It readily

invades the adult animal which is apt to become a virus carrier and may continue as such for very long periods. The sexually mature and above all the pregnant animal is the most liable to such an invasion.

A complex situation thus arises in which a non-susceptible virus carrier, the cow, harbors in its uterus a very susceptible fetus, and it is self-evident that the latter is prone to be involved in the absence of factors which are capable of either obstructing the path of the microbe or of inhibiting it in some other way. This complex nature of the problem materially contributes to the difficulty encountered in its solution.

The microbic invasion of the adult more commonly takes place through the alimentary tract. Contaminated food, drinking water or bedding are regarded as being the more common vehicles which convey the Bang organism; the devouring of parts of the afterbirths of aborting cattle by the pregnant members of the herd, while at pasture, constitutes an especially hazardous habit. As revealed by some of the later investigations, transmission of the infection by way of the genital passage does not appear to be as common as it was once considered to be. Such a mode of transmission cannot, however, be entirely excluded from the problem. Infection through the teat canal has also been suggested as a possibility.

In the affected adult animal only a few organs have thus far been shown to harbor the micro-organisms. In the female these are the pregnant uterus, the udder and the post-mammary lymph nodes, and in the male the vesiculae seminalis and the testes. In the latter such localizations are, at the most, rather uncommon and it is not certain that lesions found in connection with the infection can always be attributed to this source. The Bang microbe may have taken advantage of a *locus minoris resistantiae* caused either by mechanical injury or by an antecedent bacterial factor. The non-pregnant uterus does not appear to be a suitable abode for the organisms, which rapidly disappear from the organ after the expulsion of the fetus and its envelopes.

It is this expulsion, either as an abortion or as an apparently normal partus, which furnishes the principal means by which the organisms escape from the body of their hosts. At that time they are set free in enormous numbers, and the emptying of the infected uterus in stable or pasture constitutes the most prolific source of infection. Thus, through the act of abortion, a stable may, as it were, be flooded with virulent material.

While the uterus thus is not a constant infection reservoir from which the organisms are emitted only with the abnormal or even apparently normal termination of the pregnancy, the udder must be looked upon as a more enduring place of abode from which there is a constant escape of organisms although in more moderate amounts.

To what extent such organisms contribute to the infection danger it is difficult to estimate. Prudence demands that they be regarded as potential factors of mischief even if in this respect they can scarcely be compared with the ones set free during and immediately after the occurrence of an abortion.

The Bang bacillus retains its viability for long periods, when contained in the aborted materials. This period varies in accordance with the influences to which they may be exposed, but there is reason to believe that their infectivity may be retained for several months, especially when they are present in the filth and litter of stables.

Preventive Measures.—Abortifacient infection in the bovine as a problem in preventive veterinary medicine presents two phases, one pertaining to the infection-free herd and the other to the infected herd.

In the protection of the infection-free herd the most efficient measure consists of the guarding against the introduction of virus-carrying animals. The purchase of pregnant or sexually mature females should generally be confined to animals originating from herds definitely known to be free from abortifacient infection. The newly introduced animals should always be kept in isolation either until their pregnancy has terminated normally or until two serologic tests have indicated freedom from infection. The first of those tests should be made about two weeks after the arrival of the animals and the second one from three to four weeks after the first one. Females of breeding age belonging to the herd and returning from fairs and shows should be subjected to the same measures as the new purchases.

Herd bulls should not be used for public service, and public or common pastures are to be avoided by infection-free animals. Bull associations and breeding circuits should, by serologic tests, ascertain the status of the herds of their members, and such herds as can be proved to be infected should either be entirely excluded or be provided with separate bulls. In the organization of such associations, the statutes should establish definite provisions looking toward the exclusion or adequate management of the infection.

In large herds and in those where it is otherwise possible the advisability of maintaining a maternity stable as described in con-

nection with the management of infected herds may also be given consideration.

In view of a possible infection danger from aborting swine, contact between pregnant sows and bovines of breeding age is to be avoided.

Milk products of outside origin should be excluded altogether unless pasteurization or sterilization can be practiced.

In devising ways and means to cope with the infection of cattle after its introduction into the herd, it is profitable to take into consideration the behavior and tendencies of the disease when it is not opposed by restrictive measures. This behavior as observed in various outbreaks is by no means of a uniform character. In a number of outbreaks the disease causes great havoc during a breeding season, but during the succeeding one the abortions are not repeated or they occur in greatly reduced numbers.

In other infected herds a considerable number of abortions take place for a series of years during which the calf crop, though reduced, may yet be sufficient to meet the requirements for herd maintenance or even for a measure of profit. In such herds the losses are subject to considerable fluctuations from year to year, and it is never possible to make a dependable forecast regarding the number of calves to be expected in the course of a season.

It is quite possible that herd management exercises a notable influence on the behavior of the disease, but aside from this, it cannot be denied that abortifacient infection has a tendency to be self-limited. Although cows may continue to carry the infection, a large number among them abort only once or twice, and when they do so several times in succession, the abortions are apt to take place each time at a more advanced stage of gestation. In other instances, cows which aborted once or twice, carry a series of calves to full term and then abort again.

The cessation of abortions is commonly ascribed to a simple protective immunity acquired by the cow, and for practical purposes, it may be assumed that something related to immunity is responsible for the phenomenon mentioned.

The validity of the explanation is, however, impaired by the fact that the cow *per se,* so far as infection damage is concerned, is always immune, and by the further consideration that the fetus and its adnexa probably never are. There is good reason to believe that the fetus, no matter in what cow it may be situated, is always vulnerable to abortifacient infection, when once it invades the placenta

It is thus conceivable that the fetus, surviving unscathed in a virus-carrying cow, owes its safety more directly to something else besides the cow's active immunity, if such may be assumed. The degree of virulence of the organisms present in the cow which find their way into the placenta may be as much of a determining factor as any protection furnished by the maternal circulation. That specific antibodies in the latter can and do exercise an attenuating influence on the organisms must be granted on theoretic grounds at least, but in addition, a possible more spontaneous attenuation must also be given recognition.

The latter may be associated with the sojourn of the organisms in adult tissues and away from fetal structures, their optimum medium of growth and that in which their pathogenic powers can be best preserved and augmented. As long as the cow is inhabited by organisms, either attenuated by her immunity apparatus or by several generations' removal from fetal tissues, a fetus may enjoy safety, but the advent of infection fresh from an aborted fetus causes placental damage resulting in fetal death and expulsion. This is what probably has taken place when presumably immune cows abort again, after several pregnancies with normal termination.

In the control of the disease, the greatest consideration must be given to the animal aborting or about to do so. The act of abortion releases from the body a mass of micro-organisms, not only enormous in number but also endowed with a maximum degree of virulence. The pregnant animal, even if her uterine content is thoroughly infected, may not be a very serious menace to the other members of the herd as long as the uterus remains closed and sealed, but it is certain that, with the evacuation of the latter and for some time after, she becomes a most prolific source of danger.

The prompt segregation of the cow showing signs of impending abortion thus becomes perhaps the most important measure in the prevention of the dissemination of abortifacient infection. Even after the abortion has taken place in common stable, yard or pasture the prompt and suitable destruction of the cast-off material and contaminated bedding and foliage, followed by adequate disinfection of whatever came in contact with it, will yet have a salutary influence. The destruction of fetus, afterbirth and bedding is best done by burning, and all utensils used in their removal and handling must be disinfected with scrupulous care.

The soiled parts of the cow involved must likewise be cleaned and disinfected, after which the animal should be isolated in a place

where thorough disinfection is possible and in which her further needs can be attended to in a manner which excludes further infection spread by the lochia.

Micro-organisms will continue to be present in the uterine discharge for some time, usually for a number of weeks, but not exceeding a period of two months. The animal should, however, remain in isolation as long as a vestige of uterine discharge remains. The cow concerned should not be bred until some months after the disappearance of the discharge, and the longer breeding can be postponed the better will be the prospect that the pregnancy following the abortion will terminate in a normal manner.

Maternity Stables.—The infection hazard which accompanies actual abortions or the even apparently normal parturitions in infected herds pleads strongly for the establishment of so-called maternity stables in which all calves can be born or aborted as the case may be, and in which the infected cows can remain segregated for the required period.

In herds in which the number of breeding females is large or of a superior value, the erection of a special stable for the purpose may be warranted. When this is not the case, a part of the common stable may be partitioned off in such a manner as to preclude communication with the other part. In either case, the construction should be such that an efficient disinfection is possible, and provision should be made that the aborted materials can be adequately disposed of without contamination of any other part of the premises. Arrangements for lighting, ventilation and drainage must be of a suitable character.

In the maternity stables for the larger herds, a space should be set aside provided with facilities for heating water and for the cleaning and disinfection of the attendants and their change of garments. Wherever the size of the herd warrants it, a separate personnel should be in attendance in such stables.

Management of the Bull.—When it is not possible or desirable to maintain separate bulls for aborting or presumably infected females, the bulls should be so treated immediately before and after service so that the danger of their becoming mechanical carriers of infection may be reduced to a minimum. For this purpose, the tuft of hair near the orifice of the prepuce is to be kept clipped short, and this as well as the adjacent region is to be periodically cleaned and disinfected. The sheath and penis are to be flushed with an

abundance of mild antiseptic solution, using for the purpose a rubber horse catheter attached to an irrigator tube.

Breeding should be done on neutral ground, and the contact between the animals involved is not to be unnecessarily prolonged.

In herds in which segregation, based on serologic evidence, is being practiced, bulls giving positive reactions should not be used for the infection-free part of the herd.

Virus-carrying Calves.—In infected herds it may be assumed that infected calves are being born at the normal time or that calves are being fed with infected milk. Such calves may for a time continue to eliminate the causative organisms with the feces. Although but little is known about this as a source of infection, prudence demands that calves of infected herds should not be kept in direct or indirect contact with pregnant animals.

Infected Milk.—The now well-known fact that the Bang bacillus frequently finds a lasting lodging place in the udder has incriminated the milk as a possible vehicle of the infection. The extent of this source of infection danger is but imperfectly understood. It must be recognized, however, and milk from infected herds should not be used as food for cattle or swine, without previous heating; the hands of milkers should be also regarded as possible vehicles of infection.

The Protection of Swine.—Not only for the protection of the swine *per se*, but also in order to deny the infection the opportunity to keep up its virulence by gaining access to fetal structures, should contact, direct as well as indirect, between infected cattle and swine be rendered impossible. On the whole, pregnant swine and pregnant cattle should not be kept in the same enclosure.

Herd Management and Control.—Only under special circumstances should aborting animals be eliminated from the herd and then only for immediate slaughter. The circumstances mentioned pertain to the case in which, after the occurrence of the first abortions in the herd, a timely serologic examination reveals only a very small proportion of the herd as being infected. Such animals may be promptly sacrificed as a means of eradication.

On the whole, aborting animals should be retained and again bred after a certain period. The purchase of sexually mature animals, pregnant or not, should be avoided. If an increase of the herd by purchase be contemplated, preference should be given to yearlings or other young stock not yet of breeding age.

Herd Segregation.—By means of serologic tests the infected herd may be divided into two parts, the reacting and non-reacting animals.

Those two groups should be kept segregated from one another, and different bulls should be provided for each. In recent years the segregation method has been increasingly applied since its initial introduction in England and South Africa. The results obtained in the state-wide campaign against abortion disease in Pennsylvania, strongly indicate that it has a definite place among the measures directed against the malady. With the complete elimination of reacting animals, wherever this is economically possible, the eradication of the infection can be accomplished with finality.

Another method of segregation may be based on the fact that young animals, prior to puberty, are but rarely infected by the Bang bacillus. The method is especially applicable to cattle herds kept

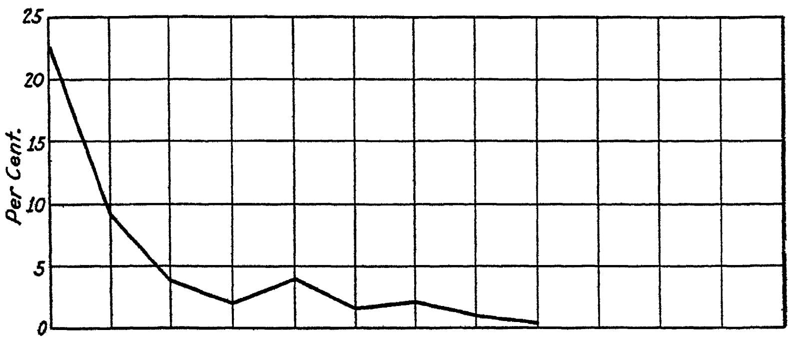

FIG. 73.—The suppression of abortion disease in the herds of fourteen institutions by semi-annual agglutination tests and the segregation or elimination of reacting animals. (After Fitz and Barnes.)

under range conditions, not permitting measures based on serologic evidence. Under its operation, the sexually mature animals are assumed to be infected, but the herd is no longer replenished by the young stock. The herd is maintained for whatever calves it may produce.

The calves, as soon as possible after weaning, are placed in separate pastures, where, without contact with mature stock, they may remain to become the foundation for a new, clean herd. If it should be possible to provide grazing ground and other facilities for the calf crops of each year, this arrangement should be given preference.

The original, infected herd should be gradually reduced in numbers and finally eliminated altogether, after which their range is to be occupied by livestock other than cattle for a season or two. After this period it can be used for the young animals born in the clean

herds. A method of pasture rotation could thus be devised by means of which the contact between adult and juvenile animals can always be prevented.

Immunization.—The fact that many cows which once or twice aborted will complete their subsequent pregnancies in a normal manner became responsible for the belief that immunity is an important factor in the self-limited features of the disease. It is not to be wondered at that soon after the discovery of the specific microorganism attempts were made to devise methods by which the resistance of the infection, expressed by the prevention of actual abortions, could be engendered in an artificial manner.

Although the term immunity is commonly applied to the means by which a cow protects her fetus, it does not seem quite certain that it can be compared to the biochemic processes by which protection against such diseases as hog-cholera, blackleg, etc., is secured. The non-susceptibility of the cow *per se* to the infection and the recurrence of abortions in cows carrying their calves normally during several pregnancies while they were persistent virus carriers are facts somewhat disconcerting to the conception of a simple and absolute immunity. In all probability the latter is merely limited to a power of attenuation by which the pathogenic functions of the virus become impaired. It is by no means certain that this quality can be imparted to the fetal tissues (placenta) which are always apt to become damaged by actual disease whenever a virulent strain of organisms gains entrance.

Something of the nature of an immunity reaction may be looked upon as a factor in the protection of the fetus, but the susceptibility of the virus to a degree of attenuation must be held as equally responsible for the cessation of abortions in infected herds.

The establishment of this protection has been sought by the usual means at the disposal of the immunologist. This includes immunization trials by means of first, immune serum; second, killed cultures; third, attenuated cultures; fourth, live cultures; and fifth, live cultures plus immune serum.

The results obtained by the use of immune serum have been unsatisfactory. It was hoped that repeated injections of immune serum in pregnant animals would establish a passive immunity sufficient to permit the completion of gestation in a normal manner, but the attempts brought disappointment.

The immunization by means of killed cultures was tried on a larger scale by a greater number of investigators. The method found appli-

cation in pregnant as well as in non-pregnant animals. The results obtained in some of the trials indicate that a slight degree of protection may thus be secured, that a reduction in the number of actual abortions could be observed, but that this reduction was not sufficient to bring about a marked depression in their incidence. Apparently there is no reason to believe that vaccination of this sort has a practical value. Even when used in conjunction with immune serum, it did not appear that the results could be improved in a striking manner.

Experiments with attenuated cultures are briefly mentioned by Zwick and his associates. Satisfactory results were not obtained, but the observers state that the unfavorable results might not have been due so much to an insufficient action of the vaccine as to the fact that they were exclusively used in young animals which are less suitable for immunization experiments than older, sexually mature cows and heifers.

The most favorable reports relating to artificial immunization pertain to the use of voluminous inoculations of living cultures into non-pregnant animals. Originally undertaken by Bang himself, the experiments were more extensively and persistently carried on by the British epizootic abortion committee. The latter made numerous field trials in the infected herds of Oxfordshire during a series of years and published its results in two reports. The first report showed that among the animals included in the experiment there were 28.9 per cent abortions before the inoculations were undertaken and that of those which received the live culture treatment the abortions amounted to 6.3 per cent whereas of the untreated controls 19.1 per cent aborted. The continuation of the treatment of the animals included in the first report brought a further reduction of the abortions to less than 2 per cent.

Experimental results obtained in Munster were no less striking. Nine herds were treated comprising 140 animals of which 64 had previously aborted; of these 64, only 3 aborted and 4 proved to be sterile after treatment. Amongst the other animals, 76 in number, which had not previously aborted and which were inoculated as a preventive measure, no abortions occurred. The percentage of abortion in the total number (140) of inoculated animals was only 2.14 per cent, or if the sterile cows were included, 5 per cent.

Favorable results were also observed by Zwick, Zeller, Krage and Gminder, who had an abundance of material at their disposal. So

far as their work pertained to the use of live cultures they could report a reduction of abortions from 29.09 to 6.36 per cent.

The authors just quoted also experimented with the use of living cultures plus immune serum and reported a reduction of abortions from 16.36 to 5.45 per cent. They further stated that pregnant animals may during any stage of gestation be inoculated with living cultures plus immune serum (1–10) without unfavorable consequences, and that in fact pregnancy appeared to favor the formation of antibodies so that non-infected pregnant animals are therefore more readily rendered immune than non-pregnant ones.

It does not appear, however, that the experiments with live cultures plus immune serum in pregnant animals have been sufficiently extensive to permit definite conclusions relating to their practical value.

On the other hand, the statistical material now available which pertains to the use of live cultures alone in non-pregnant animals has become abundant enough to deserve consideration, in spite of certain objections which have been offered to it.

In the hands of some observers, the live culture vaccination failed to bring about a reduction in the number of abortions; others disapprove of it because of the possibility, if not the probability, of increasing the number of virus carriers in the herd and by augmenting to the infection danger. To what extent those fears are based upon observed facts is not apparent, but, no doubt, the risk cannot be entirely denied. The method is certainly not to be considered in infection-free herds, but in the infected ones, in which the bacilli are being more or less continually disseminated, the objections offered lose much of their validity, and the assumed danger may be largely compensated for by advantages gained.

In the light of our present knowledge, it appears probable that live culture vaccination may be applied in heavily infected herds with some hope of its improving an already bad situation. The method cannot displace the preventive measures described above, and those must remain the principal means of control. It may prove to be a valuable supplement to those, but probably no more.

As the method is now applied, non-pregnant, sexually mature animals are inoculated with massive suspensions of live bacilli, two months before being bred. The practice should be systematically continued for a series of years if the best results are to be obtained, and it appears that these are more readily secured in animals which had aborted than in the non-infected ones.

The duration of the so-called immunity engendered by the method seems to be subject to considerable variation, and it rarely extends over more than two years.

On the whole, the control of abortifacient infection by vaccination must still be regarded in the light of an experiment, however interesting and promising it may appear. The words of caution by Zwick and his fellow workers are worthy of quotation: "The character of the disease and the different forms in which it is expressed require that the appraisal of the real value of vaccination against infectious abortion, which is entirely dependent on conception by the animals and which must be based on the observations of many years, is accompanied by great difficulties. For this reason must the reports of favorable results with the various vaccines against infectious abortion which appeared during recent times, be accepted with the greatest caution. It can be said with ample justice that until now a suitable, fully satisfactory vaccination process has not become known."

In spite of the fact that the use of live culture vaccines has been shown to have been a factor in the reduction of actual abortions, there is no evidence to indicate that it has been instrumental in a complete eradication of the disease. The use of vaccines merely constitutes a compromise and has no place in the final radical extermination of the infection.

Regulatory Measures.—In some instances legislative measures against abortifacient disease have been warmly advocated, and in some countries and states such measures have been enacted as laws. It does not appear that such laws have in any way been helpful in the solution of the problem or that their enforcement has been at all possible in the face of the wide distribution of the disease. In most states the statutes prohibit the sale or movement of animals affected with or exposed to communicable diseases in general and provide for ways and means for the recovery of damage by civil action. This is probably all that can be reasonably obtained by legislative provision until an enlightened public opinion sustains more trenchant restrictions.

If this type of infection is to be made a subject of government concern, it is probable that far more can be accomplished by efforts of instruction and by placing at the disposal of breeders expert official guidance in the management of infected herds. Such a policy may develop a public attitude in favor of restrictive measures of a more

radical nature, which without this support would remain entirely useless.

Abortifacient Infection of Swine.—The common occurrence of abortions in swine in many parts of the United States has afforded ample opportunity to establish the fact that in practically all outbreaks which were investigated the abortion bacillus of Bang is the etiologic factor. The presence of this organism in aborted materials can almost constantly be demonstrated by bacteriologic methods, and serologic tests applied to the sows involved also tend to prove its relation to the infection.

Owing to this common etiologic factor and the epizootologic features peculiar to abortifacient infection in both species, preventive measures in swine must thus be based on the same principles as in cattle and must be attempted along the same general plan.

The Protection of Infection-free Herds.—The prevention of the introduction of infected sexually mature females is the principal factor in the protection of the infection-free herd. Especially the purchase of young sows pregnant for the first time should be surrounded by adequate safeguards. Such animals should be kept segregated from the general herd until either a normal termination of gestation or two negative serologic tests made with blood serum drawn at periods some three weeks apart indicate freedom from the infection. In the purchase of swine for breeding purposes, the selection of young animals not yet sexually mature will probably be accompanied by the least risk of infection.

A further factor in the protection of the non-infected herd is the avoidance of contact between brood sows and breeding cattle, whether the latter are at the time infected with the Bang organism or not. The indirect contact with cattle by means of milk or milk products must also be prevented. Whenever such foodstuffs are to be utilized in a herd of swine they should be rendered safe by previous pasteurization and especially so when they originate from outside sources.

On account of the great prevalence and wide spread of the Bang infection in both cattle and swine, the management of pregnant sows should anticipate the introduction of the disease by dividing the animals into as many separate groups as circumstances permit. A particularly mischievous factor in the spread of swine abortion may thus be avoided, namely, the simultaneous infection of the greater part of the pregnant sows through their devouring the materials cast off by the first animal aborting.

By maintaining the sows in small, separate groups, the process of the infection, once it is introduced, can often be so much delayed that a considerable number of normal parturitions occur, which otherwise might have been rendered impossible by the infection.

The Management of the Infected Herd.—As in cattle, the actual occurrence of an abortion among a group of brood sows is the most potent factor in the spread of the disease. All that is possible should be done to prevent this happening, and if in spite of all efforts an abortion has taken place, all should be done to reduce the infection risks to which the other sows are exposed. They should be promptly removed to grounds or premises not previously occupied by swine apt to be infected and, if possible, should there be divided into small groups in the manner indicated above and for the same reasons.

If in the aborting sows no secondary infection intervenes, they may be bred again, but this should be delayed as long as practicable and should not be undertaken in less than two months after the disappearance of the vaginal discharge following the expulsion of the uterine contents.

It is entirely feasible to bring about the separation of the animals of a given herd into presumably infected and non-infected groups by means of the serologic tests. These groups must then be kept entirely segregated from one another and special boars be set aside for each lot. The boars intended for the infection-free part of the herd should also be shown to be infection free by serologic evidence. Boars used for sows which have aborted should not be used for young sows to be bred for the first time.

If the aborted materials are accessible, they should be carefully destroyed and all objects with which they came in contact should be disinfected in an approved manner.

It is not known that any method of artificial immunization can be profitably employed in the control of abortifacient infection of swine.

Abortifacient Infection in Mares. *Cause.*—The abortifacient infection in mares responsible for the more or less extensive occurrence of abortions in certain studs or even in certain breeding districts is commonly to be attributed to some representative of the colon-typhoid group of micro-organisms. There is bacteriologic evidence that the organisms implicated in the various outbreaks cannot constantly be determined as belonging to one and the same species. They show certain differences in their cultural characteristics, although their relations to the group mentioned cannot be questioned. The most commonly identified organism in equine abortion is designated as

Bacillus abortus equi, but as further causes of the disease strains representative of the paratyphus bacillus and the Gärtner bacillus also require to be considered.

The infection appears to be principally introduced by means of contaminated food and drinking water. Infection by sexual contact, though not absolutely to be excluded, does not seem to play a prominent part, and the same can be said of a possible introduction of the virus into the vagina and uterus by means of soiled bedding. The organisms present in the fetal membranes, the fetal fluid and the vaginal discharge pollute stable floor, bedding, feed and water, and contained in these substances they are taken in by the inhabitants of the stables, paddocks and pastures.

Preventive Measures.—In horse-breeding districts in which abortion is to be especially feared, all contact of the various stables with one another and with outside establishments should be avoided. Parturient mares or those in which abortion is apparently impending should be promptly isolated in stalls separate from the common stable where all infectious material can be so disposed of as to avoid the dissemination of the infection and where an adequate disinfection is possible. Sanitary stable construction, permitting thorough cleanliness and disinfection, is a valuable asset in the prevention of the disease. The protection of the food and water supply against contamination must not be neglected.

Those measures must be even more scrupulously applied in studs in which abortions have occurred. The mares involved in the infection and those which aborted should be kept segregated until all evidence of uterine infection has disappeared; during that time they should receive adequate veterinary attention for the purpose of freeing the uterus from infectious material.

In order to allow the uterus sufficient time for the re-establishment of a normal status, a mare should not be bred until at least two or three months after an abortion. As a supplementary safeguard against the spread of the infection the stallion should be disinfected immediately before and after service.

There are indications which tend to show that in the control of the infection immunization may be of material assistance. Good, Good and Smith, Kelser and Mieszner and Berge report favorable results after vaccination in which killed cultures were used. Good prepared his vaccine by streaking an agar slant in a test tube 1.75 cm. by 15 cm. The culture was then incubated for 24 hours and washed with 10 c.c. of physiologic salt solution into a sterile bottle containing

glass beads and filtered through cotton flannel in order to remove bits of agar. The bacteria were then killed by heating in a water bath at 70° C. for 2 hours after which the sterility of the suspension was determined. One cubic centimeter of this vaccine contained about 8500 million organisms.

The subcutaneous injection of large doses of this material into pregnant mares produced no ill effect other than an occasional abscess at the seat of inoculation, and the mares injected delivered healthy colts.

Good recommends that mares be treated 4 times, 8 days apart, by subcutaneous injections of 1 c.c. for the first treatment, 2 c.c. for the second, 3 c.c. for the third and 4 c.c. of double strength for the fourth.

Mieszner and Berge prepared their vaccine by killing the cultures by heating at 65° C. for 3 hours and a subsequent shaking with glass beads for 24 hours. Three vaccines of increasing strength were used, and each vaccine was injected subcutaneously during the second, third and fourth months of gestation. Frequently another injection with vaccine No. 3 was made during the fifth month of pregnancy.

There are indications which show that preference should be given to vaccines prepared from the organisms isolated in the studs to be treated.

Attempts to secure a passive immunity by means of immune serum were also made, but the results were, on the whole, disappointing.

Abortifacient Infection in Sheep.—Our knowledge regarding the abortifacient infection of sheep is very incomplete. Although abortions apparently caused by some microbic factor are observed in these animals from time to time, it does not appear that there occurs in sheep a preponderating specific infection, such as is known to be identified with cattle, swine and mares.

Commonly the mass abortions in ewes were found to be the result of systemic diseases, such as foot and mouth disease, sheep-pox and others. In a few outbreaks the Bang bacillus may have been associated with the disease; in others a vibrio was identified as a cause.

Preventive Measures.—In the absence of very definite information regarding a more or less constant etiologic factor and its behavior, a specific method of control cannot be urged at this time. For the present, outbreaks of abortifacient infections in sheep can be faced only with general sanitary measures. Among these may be mentioned the prompt removal of the pregnant ewes to another

range, pasture, lot or premises, and a complete change of feed and water.

The usefulness of the prompt destruction of aborted lambs and afterbirths and of the segregation of the ewes which aborted or which show signs of approaching abortion is quite obvious. If at all possible, aborting ewes should be eliminated from the flock altogether.

Those measures are to be complemented by the disinfection of sheds, stables and such utensils as were used in the removal of the aborted material.

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CHAPTER XXIII

ANTHRAX

ANTHRAX is a febrile transmissible disease usually of a septicemic character, affecting cattle, sheep, horses and swine, and due to the presence of a specific etiologic factor, the *Bacillus anthracis*.

In the susceptible species the disease may manifest a peracute, acute or subacute course, but in the resistant ones a more or less chronic form of the disease is not unknown. The acute forms are especially observed in the beginning of outbreaks, during which the mortality is also the highest. Toward the last of an outbreak the disease may show even something like a benign character. The average mortality fluctuates between 70 and 90 per cent for such animals as cattle, sheep and horses.

Anthrax has been observed during all times and in all parts of the globe from the extreme polar regions to the torrid zones (Roloff). It is very apt to be permanently associated with certain localities which are sometimes narrowly defined without the disease invading adjoining territory. Certain fields, like the "champs maudits" of the Beauce in France are notorious for the anthrax hazards associated with them. Occasionally the disease shows a tendency to cling to certain stables in which cases are apt to occur at irregular intervals for an indefinite period.

In the established anthrax districts the disease may occur sporadically or enzootically, and formidable epizootics have frequently been recorded. In many such infected areas anthrax appears off and on, sometimes only in the course of certain years, whereas in others, outbreaks are a perennial occurrence; wherever the disease is seen at all, regular outbreaks may be expected.

In certain countries like France, England and Germany, the incidence of anthrax has steadily declined. This was statistically shown for the latter country for the period beginning with the eighties of the last century, the data indicating that toward the end of that century about 85 per cent of the reported outbreaks pertained to one animal only.

In the interior of Asia, in South and Central America, as well

as in Africa, anthrax, to this day, frequently assumes an enzootic form. From a sanitary standpoint it is quite significant that from these countries raw products of animal origin are being exported to be used by the industries of others, where they not uncommonly become responsible for the establishment of infection centers.

Susceptible Species.—Herbivorous animals show the highest degree of susceptibility. Cattle, sheep, goats, horses contract the disease quite readily, although their relative liability to infection may vary with the locality of the outbreaks. In France, for instance, sheep are most commonly involved, whereas the anthrax incidence for this species is much lower in Germany and England. Horses show a tendency to escape the disease in France and in Central Europe, whereas in Russia and Siberia they are commonly stricken, a feature observed also in some of the anthrax foci of North America. In most countries, with few exceptions, cattle furnish the greater number of cases, but in the regular outbreaks other livestock is always in jeopardy.

Buffaloes, camels, deer, mice and cavias are quite susceptible. Rabbits are but slightly less so, and in this respect the varieties of rats show a great divergence *inter se.* The elephant may succumb to the disease. Swine show a marked degree of resistance, although this may also vary with locality. The carnivora are even more resistant, but in spite of this quality the disease has been observed in the dog, cat, lion, tiger and others (menagerie outbreaks).

Man is susceptible to anthrax; it constitutes for him one of the important industrial diseases (wool-sorter's disease, malignant carbuncle in tannery workers, etc.).

The common fowl resists natural infection; the pigeon is a little less resistant. Spontaneous anthrax was observed in the duck. A degree of susceptibility cannot be altogether excluded in the cold-blooded animals like the reptilia, the batrachians and some of the fishes (*Hippocampus*).

The Virus of Anthrax.—The *Bacillus anthracis* is the specific etiologic factor of anthrax. This organism was the first one identified as the specific cause of disease, and with this discovery modern bacteriology may be said to have been inaugurated.

From a hygienic standpoint, the most important character of this organism is its capacity to form a highly resistant spore. This pertains to the majority of the bacillary strains. There are also strains which are apparently not endowed with this quality. It is even possible by artificial means to change a sporogenic strain to an asporogenic one, although the reverse has thus far not been achieved.

Sporulation is subject to certain definite conditions. These are: a suitable temperature (16 to 43° C.), the contact with free oxygen and the presence of adequate nutrient substances. Spores do not form in the living animal body or in the carcass, apparently because the available oxygen is being consumed there by the bacteria of putrefaction. However, if the bacilli are exposed to the air by the opening of the carcass or if they are contained in the body discharges, sporulation is apt to come about with promptness.

The bacilli are capable of growth at temperatures ranging between 15 and 43° C. The optimum temperature is somewhere near 35° C. Above or below this the virulence may be reduced.

The anthrax spores may vegetate outside the body in the soil and the water while contained in it. Hence the organisms may appear as parasites and as saprophytes. Largely on account of the highly resistant character of the spores which find their way into the soil the latter constitutes the more common reservoir for the virus and is in consequence the chief source of infection.

The bacilli are contained in all parts of the carcass, especially in the internal organs. In the living body the organism, in conspicuous numbers, only appears in the blood shortly before death.

The non-sporulated bacilli are relatively fragile. They succumb within a period ranging between 6 days and 2 months, according to the temperature of the media in which they happen to be present. They are sensitive to direct sunlight in the presence of oxygen and may be killed by exposure in from 10 to 16 hours. In the absence of oxygen the rods may survive an exposure for 83 days. Sunlight acting on sporeless bacilli contained in blood destroys the virulence in 8 hours, and in 14 hours in the moist state if the blood is in contact with the air.

The effect of desiccation on the non-sporulated organisms is rather a slow one; they may resist this influence for 60 days at ordinary temperatures.

The bacilli *per se* are sensitive to heat, and either in fresh blood or in cultures they succumb to a 40 minutes' exposure at 55° C., to one for 1 hour at 50° C., to one of 2 to 4 minutes at 75° C. and at 80° C. the organisms are killed in 1 minute.

Organisms without spores do not live long if contained in putrid material. In decomposing blood they remained viable for from 8 to 20 days, whereas if the blood was dried, they survived for from 36 to 50 days.

The bacilli are readily influenced by the action of certain chemical

agents. The latter either check their development or destroy their viability altogether. Development is suspended by sublimate (1:300,-000), by iodine (1:5000), by phenol (1:3000), by boric acid (1:800). The organisms are killed by sublimate (1:30,000), by formaldehyde (1:20,000), by saponified cresols (1:15,000) and by phenol (1:100 to 200).

The resistance of the spores to adverse influences, on the other hand, is extremely well marked. Anthrax spores were found to be still virulent after a storage of 18½ years, and it was observed that they apparently gave rise to an outbreak of disease after the accidental opening of a burial pit in which anthrax carcasses had been disposed of 24 years before.

It is probable that the spores in the deeper soil layers will survive for indefinite periods if sheltered against light and air, but it has been shown that contained in water, they retained their virulence for more than a year. In another observation, they were found to have survived a storage for 29 months in sterile, distilled water. If the latter were agitated they survived for 20 months; contained in sea water, they retained their viability for 21 months, but in moist earth they lasted for not less than 33 months.

Desiccation has no effect on the spores, and apparently the action of direct solar radiation is not a very marked one. To heat, also, the spores show a marked resistance. They withstand a moist heat of 95° C. for 10 minutes at least, but succumb to a similar exposure at 100° C. from 3 to 4 minutes. Dry heat destroys the spores but slowly, and a temperature of from 120 to 140° C. prolonged for 3 hours was required to accomplish their destruction.

The resistance of the spores to chemical action is equally well marked. They were found to be still virulent after an immersion in glycerin for 281 days and one in absolute alcohol for 124 days. They remained alive in a 1 per cent solution of phenol for 61 days, in a 2 per cent solution of the same substance for 30 days, in a 0.1 per cent solution of sublimate for one hour and in a 0.01 per cent solution of sublimate for 42 days. It required 8 days in a 5 per cent solution of phenol to kill the spores. The spores of 64 per cent of the anthrax strains tested remained alive for more than 75 days in a 33 per cent suspension of quicklime.

Formaldehyde apparently is more potent in its destructive effects on anthrax spores. A 1 per cent solution destroyed the spores in 2 hours; they are killed in 1 hour by solutions of from 2 to 5 per cent, and a solution of from 10 to 20 per cent kills them in 10 minutes.

The determination of the resistance of the anthrax spores by experimental methods has, however, revealed a considerable variation for the different strains; in actual practice the action of adverse conditions is, no doubt, still further modified by the nature of the media in which the virus is contained as well as by certain physical conditions.

Modes and Vehicles of Infection.—As anthrax occurs in nature it is not transmitted by contagion. Although the animal body probably serves as the incubator for a preponderating portion of the virus distributed in nature, the virus, as a rule, invades new hosts only from some extra-corporal reservoir as its starting-point and through the agency of various vehicles. One animal in a herd may succumb to the disease while all its companions escape infection, or the disease may suddenly appear in a stable without the least evidence of direct transmission from one animal to another.

The principal virus reservoir is the soil, and this is especially the case in the more permanent infection foci. Although the propagation of the anthrax bacilli in the soil must be given consideration, it is quite reasonable to believe that after all, the spores, there present, were for the greater part, at some time or other, derived from animals sick or dead with the disease. In support of such a view it is quite significant that in many districts which formerly showed an extraordinary anthrax hazard the incidence of the disease became conspicuously reduced if for a number of years the animal population was protected by immunization, so that in the end unprotected animals became quite safe.

Soil contamination comes about in various ways. The skinning or opening of carcasses during which blood or other virulent substances become scattered about on the surface is an especially potent source of mischief; the ejecta of affected animals deposited on the ground also play a conspicuous part in soil contamination. The careless and shallow burial of animals dead with the disease must likewise be regarded as a source of soil pollution, and hence old burial grounds are always to be suspected of being reservoirs of anthrax virus, at least in districts where the disease was once established.

Such areas are, however, not the only ones where soil contamination must be given consideration, because the disease may be introduced in hitherto clean territory by the importation of fertilizing materials from infected regions. Wastes from tanneries and other industries using imported raw materials of animal origin have become notorious in the establishment of new anthrax centers. Ma-

terials, as skins, bones, wool, hair, are apt to carry the spores which eventually find a resting place in the soil. The germs are scattered about with the dust or are transported while attached to containers, to the floors of railway cars, or the decks of vessels whence they may find their way into the bilge water.

Water plays an important part in the distribution and transportation of the spores and likewise may serve as a vehicle by which they are carried directly into the animal body. Surface water readily conveys the virus, and in the course of inundations, through the water from infected areas, the spores are deposited on new lands, meadows and pastures. Streams receiving the wastes of tanneries or similar industries are particularly active in the dissemination of the infection and in the establishment of new foci.

Food and drinking water derived from infected soils are the principal vehicles by which the virus is introduced into the animal body. Feeds and forage grown on infected lands or on ground subjected to overflow are always to be feared unless the latter are quite remote from anthrax districts. Regular outbreaks have been observed after the use of feeds imported from anthrax countries, and even fish and meat meal derived from such sources apparently may serve as vehicles for the virus.

Not only may anthrax spores be carried from the soil to the surface of growing vegetation, but the ejecta of affected animals may directly contaminate the plants as well as other foodstuffs.

Carnivorous animals may become infected by the consumption of the flesh of infected carcasses, and nurslings have been observed to contract the disease by the ingestion of the milk of infected animals.

The spores of anthrax confined for long periods in relatively safe places may be brought to the surface and subsequently contaminate the feed and forage. The taking up of old stable floors and the cleaning of water courses has been followed by outbreaks, and various carriers may be instrumental in the transportation of the spores, the contamination of food and water, and even in their introduction into the animal body.

The virus may remain latent in the body of certain animals which may become carriers for it. Such a possibility is particularly associated with animals belonging to the less susceptible species (swine, dogs, rats). In swine, more or less chronic lesions of the intestinal walls and the lymph nodes are occasionally found, and as this type of infection is rather benign there is a prolonged opportunity for virus dissemination.

Dogs, as well as fowls and pigeons, feasting on anthrax carcasses, may serve as carriers, for the spores may pass through the digestive tract quite unharmed. Buzzards and other carrion birds may convey the spores in a mechanical manner by the soiling of their external parts or by their being contained in the vomited materials when too copious a meal derived from an anthrax carcass is disgorged.

Transportation of spores by rain, worms, snails, insects, and the larvae is always possible, and even scavenging fishes may serve as vehicles of the infection.

Flying insects may transport the virus or even be the instruments by which it is inoculated. It was shown experimentally that the common house fly (*Musca domestica*), the blue and green bottle flies (*Calliphora erythrocephala, Lucilia Caesar, Lucilia sericata*), are capable of carrying anthrax infection to wounds of healthy animals after having fed upon infected flesh. However, flies bred out of an unopened carcass do not seem to convey the spores.

The horn-fly (*Hematobia irritans*), the horse flies (*Tabanus*), the stable fly (*Stomaxys calcitrans*), mosquitoes (*Psorophora sayi, Aedes sylvestris*) are able to act as vectors for the virus of anthrax. Biting flies may introduce the infection through the skin, and a similar inoculation may result from the bites of other animals (sheep-dogs).

The intact skin does not lend itself to the absorption of the virus, and even through the more external mucosa this takes place only with difficulty. On the other hand, wounds, even the more trivial and superficial ones, readily provide a means of entrance for the virus.

The digestive organs are the usual ports of entrance in the natural infection, and especially are the spores apt to enter the circulation through the intestinal mucous membranes. All traumatisms of the digestive mucosa favor the invasion; in the herbivora, this commonly comes about by the presence of coarse, hard and dry vegetable substances in the food or by parts of thorny plants. In swine, tonsillar ulcerations frequently serve as primary entrance ports for the virus.

Although in the ruminants alimentary infection is practically the exclusive one, it has been estimated that in horses in about 55 per cent of the cases the infection is alimentary whereas in 45 per cent it is attributed to insect stings. No doubt, such observations may lead to varying conclusions in accordance with locality and season.

Respiratory infection is not to be excluded as a possibility and is especially observed in man (wool-sorter's disease).

Initial infection is practically always associated with the introduction of the spores. The severity of the infection is dependent on the

number of the spores and the virulence of the strains to which they belong. There is evidence to show that the process of pathogenesis is not a simple one, and that in all probability certain soluble substances derived from the organisms (aggressins?) play a part in the infection process. Once the process is under way, the dissemination of the organisms takes place with great rapidity, especially in the more susceptible animals, the lymph and blood circulatory apparatus constituting the highways used by the invading parasites.

Factors Favoring Infection.—Specific and individual susceptibility is the foremost among the factors which favor anthrax infection. No doubt this may vary, and this variation may be expressed by such phenomena as sheep being the most common anthrax hosts in some countries, whereas cattle are more frequently attacked in others. It ranges between the perfect resistance of the animal which recovers from an attack of the disease to the marked susceptibility of another which is struck down suddenly by its peracute form. The existence of breed differences in susceptibility within a given species is well shown by the marked resistance to anthrax infection manifested by Algerian sheep, as well as by that of the white rat as compared with the common wild varieties.

Age exercises a certain influence on the liability to anthrax of individuals belonging to the same species, and as a general rule the younger animals contract the disease with more readiness than the older ones. The action of the virus of anthrax on the animal body is further favored by such depressing conditions as hunger, chilling, weakness, fatigue, overwork and faulty feeding.

The incidence of anthrax is affected by seasonal influences. Among animals at pasture the disease is usually more frequent during late summer and autumn, although in regular anthrax territory cases may be encountered throughout the year. If the infection is associated with certain stables, outbreaks or sporadic cases may be expected to occur regardless of season.

Meteorologic conditions and the nature of the soil are reputed to influence the prevalence of the disease. The humidity and temperature of the soil as well as the state of the vegetation it sustains appear to be factors favoring the disease. A loose, warm soil rich in organic matter and lime, as well as swampy, peaty areas underlaid by an impervious subsoil, are especially suitable for the establishment of permanent infection centers.

Prophylaxis.—In the prophylaxis of anthrax two principal lines of attack may be recognized. In one the efforts are directed against

the danger threatening an animal population occupying more or less permanently infected areas, and in the other it is the aim of the sanitarian to prevent the establishment of new foci.

In permanently infected territory, reliance is chiefly placed upon the protection of the livestock by methods of immunization, consistently applied as a routine practice; sanitary measures directed toward the destruction of available virus and the amelioration of the soil conditions also have a definite place in the general scheme of prophylaxis.

For the protection of anthrax-free territory, consideration must be given especially to the prevention of the introduction of infected animals and raw material derived from them, either by challenging their harmlessness before importation is permitted or by a close supervision of their utilization. In this pursuit, sanitary police measures must be especially relied upon.

In addition to these chief objects of prophylaxis, sporadic cases must never be neglected but should be surrounded by all available means that promote the safety of environment and the livestock inhabiting it.

Sanitary Measures.—General sanitary measures taken either by individual initiative or as prescribed by livestock sanitary laws and regulations have an important place in the prevention of anthrax. Particularly the efforts put forth in the face of actual outbreaks may have no little bearing on the future anthrax morbidity on the farms or ranches concerned.

The adequate disposal of the carcasses dead with the disease is always most imperative. It is in these that a large amount of virus can be safely disposed of or destroyed. If at all possible, preference should be given to incineration, and this should be done without the contamination of the environment, a principle which should be kept in mind also when the alternative of burial has to be considered.

Anthrax carcasses must never be opened, and hide or skin must remain *in situ* and should not be cut into. The skinning and opening of carcasses not only gives rise to a gross contamination of the soil, stables or other objects, but the bacilli thus set free and brought into contact with the atmospheric oxygen will be enabled to sporulate. The spores thus formed are apt to establish new foci or to replenish the stock of virus already present.

For obvious reasons, the burning of the carcass must be carried to completion; in the case of burial the pits must be made at maximum

depth and with regard to the sanitary safety of the locality selected as burying ground.

Even though direct-contact infection plays a rather subsidiary part in the spread of the disease, it is, nevertheless, prudent to segregate affected or exposed animals and to destroy their body wastes, as well as the manure, the bedding and foodstuffs apt to have become contaminated. This should be done in a manner similar to that applied to the carcass, giving preference to destruction by fire if possible. Infected premises and objects exposed to contamination should be subjected to a thorough disinfection, for which purpose solutions of formaldehyde (4 to 6 per cent) are perhaps the most dependable.

All susceptible animals inhabiting premises or pastures where the disease has broken out should be segregated on safe ground and kept under supervision for not less than two weeks, whether they are protected by immunization or not.

The use of foodstuffs originating in anthrax districts or on farms known to be infected should be scrupulously avoided, and the wastes, of industries utilizing imported raw materials of animal origin must be regarded with suspicion and should be destroyed by incineration.

The importation of hides from anthrax-infected areas has always been a fertile means for the dissemination of anthrax. This is well shown by statistical evidence collected in Germany before, during and after the last war period in the course of which this source of infection was effectually closed. Anthrax cases were reported as follows:

Year	No. of Cases
1914	7181
1915	2398
1919	745
1923	1598

Various methods to disinfect imported hides or to render innocuous the various industrial wastes have been proposed and employed. It was found, however, to be extremely difficult so to treat the hides as to destroy the spores they might contain without rendering them unfit for industrial purposes.

The methods which gained some favor are those proposed by Schattenfroh and by Seymour-Jones. In the former, the hides are acted upon for 48 hours by a solution containing 2 per cent hydrochloric acid and 10 per cent sodium chloride. In certain instances this method proved to be successful and was found to be superior to others.

The original Seymour-Jones method consisting of treatment with a

solution of sublimate (1:5000) to which 1 per cent of formic acid had been added proved to be ineffective even when the subsequent neutralization of the disinfectant was omitted. If the quantity of the sublimate was doubled and the neutralization by a 1 per cent solution of sodium sulphite was omitted the treatment proved to be efficient.

If the disinfectant was neutralized, the material treated was shown to be virulent after the conclusion of the experiment. If the method is to be employed, neutralization should not be attempted, and the action of the disinfectant should be prolonged for from one to two weeks.

On the whole, actual experience with the treating of hides has not shown a very conspicuous success; of late a measure is being inaugurated in Germany by which the hides are examined by means of the Ascoli precipitation method and are released for industrial purposes only if a negative reaction is obtained.

The treatment of the wastes and residues arising from industrial processes likewise has not been particularly successful. One method proposed was the composting of the solid wastes with 20 per cent quicklime for a period of three months and the treatment of the fluid wastes after chemical or mechanical clarification with commercial sulphuric acid. All such attempts are expensive, and although they may reduce infection hazards to a degree, they apparently cannot fully prevent the occurrence of disease among livestock exposed to this type of waste matter.

Land improvement by drainage, the exclusion of livestock from infected pastures and the provision of safe drinking water must be regarded as additional factors valuable in prophylaxis.

Immunization.—The usefulness of sanitary measures in the prophylaxis of anthrax is a generally well-established fact, but it is also certain that, without the application of artificial immunization, but little progress would be made in the prevention of the disease. Not only is this a means of saving the lives of exposed animals, but it also constitutes a complement to sanitary control measures by denying to the virus its optimum soil for development and reproduction: the animal body.

There can be no doubt that by the persistent and systematic application of artificial immunization the future incidence of the disease, as well as the actual one, are beneficially influenced in a prophylactic sense.

Under the effect of continued immunization during a series of consecutive years the epizootology of anthrax becomes favorably modified.

In the established foci of infection the prevailing morbidity rate points to the ubiquity of the virus, but if in such a district immunization is carried on annually the disease becomes progressively less frequent and there is ground for the belief that in such an area it can be made to disappear altogether.

Various methods of immunization are in use at the present time, and others have been proposed.

Pasteur's Method.—This method, by which the master ushered in a new epoch in the struggle against disease, depends on the use of attenuated virus used as vaccines. It requires two distinct inoculations. The first one with a culture attenuated to the extent of having its virulence almost entirely removed is followed after 10 or 12 days by the second inoculation in which a less attenuated and thus slightly more virulent culture is used.

From 10 to 12 days after the second vaccination the immunity acquired by the animals is sufficient to protect them against natural infection. In very badly infected territory a third vaccination 10 to 13 days later, in which a less attenuated vaccine is injected, is occasionally deemed advisable.

The protection conferred by means of the Pasteur vaccines endures for a period extending from 5 months to 1 year, and in the event of a continued infection hazard the vaccination should be repeated every year.

Such a routine vaccination is best undertaken about 6 to 8 weeks before the beginning of the pasture season.

For approximately 10 days after the vaccination there is a transitory increase in the susceptibility to anthrax (negative phase) on the part of the animals treated, and hence they should be kept in a place where they are protected against exposure to the virus.

The results obtained with the Pasteur method are generally satisfactory even if failure is now and then recorded. Vaccination anthrax is not always to be excluded, and data are available which showed that such losses amounted to 0.08 per cent for horses, to 0.02 per cent for cattle and 0.12 per cent for sheep. Failure to secure the desired degree of protection pertains to 0.05 per cent for horses, to 0.03 per cent for cattle, and 0.06 per cent for sheep.

Cienkowsky's method, in use in Russia, brings about the same results as those obtained with the Pasteur method. It depends on the use of attenuated spores and has the advantage of a greater durability of the vaccines which extends over years, if they are stored in a cool,

dark place. Spore vaccines are used elsewhere, and in Japan they are preferred to the Pasteur cultures.

Sobernheim's Method.—In its usual application this method consists of the simultaneous injection of a very potent serum obtained by hyper-immunization of horses, asses, cattle and sheep and of a suspension of attenuated spores and bacilli. The serum is injected on one side of the body and shortly after this the culture suspension is injected on the other side.

The method, though more costly than the preceding ones, offers the advantage of rendering protection available at a much earlier period than if the Pasteur method is employed. The immunity thus established is reported to endure from ½ to 1 year.

The serum retains its potency for an indefinite period, whereas the suspension of the organisms necessary to bring about active immunity should not be used if more than 10 days old. Hence in the place of bacillary suspension spore vaccines have been recommended.

In badly exposed herds one vaccine injection may not be sufficient and may therefore be followed by three or four subsequent injections with increasing doses of the vaccine at intervals of two weeks (hyperimmunization).

In the event of imminent infection danger in herds in which anthrax cases have already occurred, passive immunization by the application of serum injections is to be attempted. The protection thus established is immediately available, but is of only a short duration (1 to 2 weeks). Thus, in the case of continued exposure, there is need of having recourse to any of the methods by which an active immunity may be conferred.

Bail's Method.—Bail found that, when an experimental animal is treated with the edematous or other body fluids of animals dead with anthrax, the aggressins present, acting as an antigen, gave rise to the production of anti-aggressins in the animals so treated, and that these bring about a subsequent active immunity. Based upon this observation and the principle involved, the edematous fluid of anthrax-infected animals, freed from bacilli or spores, under the name of "anthrax aggressin" has been introduced into practice as a means of establishing an active immunity. Results obtained in the field appear to have been favorable, and if they can be confirmed by further observations, the advantage of such a method is quite obvious. The vaccinating substance is sterile and only one injection appears to be required for the purpose in view.

Besredka's Method.—This method introduced in practice during recent years is less dependent on a specially prepared immunizing agent than on the manner of its inoculation. The latter is associated with the prominent part played by the skin as an organ primarily responsible for the defense of the body by immunity. Hence the vaccinating substance (Pasteur's second vaccine or spore vaccine) is injected intradermically, once or twice, as the operator deems expedient.

The immunity thus conferred is spoken of as being "explosive," the vaccination causing the cessation of the outbreaks within 48 hours in the severest of epizootics and that without the use of serum. Other observers reported that a solid immunity is available from the fifth day on and perhaps sooner. The duration of the immunity has not yet been definitely established, but animals were found to be refractory to infection from 6 to 7 months after the treatment.

Some observers use 2 punctures 6 days apart; others maintain that the intradermic vaccination with a single vaccine brings about a solid and durable immunity. The method appears to be gaining favor for use in the French African colonies (Morocco). It seems prudent to await further reports before the older, well-established methods are abandoned in favor of this method, however promising it may otherwise appear.

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CHAPTER XXIV

BLACKLEG

The disorder designated as blackleg, black-quarter or symptomatic anthrax may be defined as a non-contagious, infectious disease caused by a specific micro-organism, the blackleg bacillus (*Bacterium chauveaui*). The disease, septicemic in character, enzootic in its occurrence, and generally fatal, manifests itself clinically by an acute, febrile disturbance and most frequently by the formation of emphysematous swellings in the large muscle masses and occasionally by the presence of similar lesions in other organs. Patho-anatomically the lesions consist of a more or less extensive, dark colored, dry or moist gangrenous degeneration of the tissues, accompanied by a secondary enlargement of the lymph nodes.

Although it is not always possible to differentiate it clinically from other specific infections which may give rise to emphysematous gangrenous processes, blackleg, as a distinct, morbid entity commonly constitutes a problem in preventive veterinary medicine which cannot be neglected without the risk of conspicuous death losses among the livestock more particularly concerned.

The Virus of Blackleg.—The blackleg bacillus is an anaerobic, spore-forming microbe, from 5 to 8 microns in length and 1 micron in thickness. The organisms are always abundantly present in the lesions, in the peripheral edematous areas, and in the lymph nodes of the affected regions. The intestinal contents of animals suffering from the disease are usually virulent. The virus is to be found less constantly in such organs as the spleen, liver and lungs. The serous fluids, the bile, the urine frequently contain it; the bacillus has also been observed in the milk and the aqueous humor. During the latter stages of the disease a relatively small number of bacilli may make their appearance in the blood.

The microbe causing blackleg is further to be found in the soil of the districts in which the disease habitually occurs and is frequently present in the digestive tract of the normal cattle inhabiting such regions. The soil is contaminated by the virus set free from carcasses in the course of their decomposition and by the droppings

of live animals, either those affected by the disease or those which, though in good health, harbor the bacilli in the intestinal canal. It is by no means improbable that normal animals constitute an important source of blackleg virus and that they serve as incubators from which the pollution of the soil is constantly replenished.

The infection source associated with the soil is a durable one, a fact, that is in no small measure caused by the readiness of the organisms to form spores and by the marked resistance of these spores to adverse external influences.

The spores are not deprived of their viability by drying and when contained in desiccated material they are extremely resistant even to such influences as heat. Putrefaction but slowly destroys their virulence, and blackleg carcasses, exposed for 6 months or more to the open air, still contain the virus in full possession of its original pathogenic properties. In some cases the virulence of such material was found to be preserved for many years.

The resistance of the spores to heat is a considerable one. When contained in the affected tissues, they may lose their virulence only after an exposure to a temperature of 100° C. for 20 minutes; at 70° C. an exposure of 2 hours and 20 minutes is required; at 80° C. a heating for 2 hours is necessary, and even then the virulence is not always destroyed and their viability is usually preserved.

The action of antiseptics is largely modified by the medium in which the virus happens to be contained, the latter on the whole showing a marked resistance to their influence. A 5 per cent phenol or lysol solution failed to destroy the germs in the skins of blackleg carcasses after an exposure of 4 weeks' duration. A 0.1 per cent sublimate solution was more efficient but rendered the hides unfit for technical purposes. On the other hand, a pickling fluid containing 2 per cent hydrochloric acid and 10 per cent sodium chloride destroyed the spores in 24 hours, without damaging the hides (Maasz).

It is this marked resistance of the virus to external influences which is responsible for the permanency of infection centers and to which the recurrence of the disease, year after year, is principally due. It renders an effective eradication of the disease extremely difficult, if not impossible altogether.

The pathogenesis of blackleg does not appear to be a simple process, as the specific virus freed of its products by thorough washing is no longer virulent, but requires the addition of small quantities of activating substances, known as aggressins, in order to enable it to exercise its pathogenic functions. It was shown experimentally that

foreign substances, such as glycerin and others, may exercise a similar activating influence. It is probable that, in spontaneous infection, tissue injury and the presence of other micro-organisms otherwise more or less harmless may promote disease production either directly or indirectly by favoring the development of the specific aggressins essential to pathogenesis.

Host Species.—Blackleg presents itself as a disease most particularly affecting the bovine species. Under special circumstances, sheep also may contract the disease, and this animal has been shown to be remarkably susceptible to artificial infection. It is doubtful that the blackleg bacillus causes spontaneous disease in other animals, although goats and cavias may be successfully infected by inoculation. Horses and swine are resistant to the infection, and blackleg has never yet been found to occur in man.

Modes and Vehicles of Infection.—Blackleg infection does not come about by a direct transmission of the virus from animal to animal. It is usually soil-borne, and although wound infection may take place, the majority of the cases derive the virus directly from the soil or from the vegetation grown on contaminated ground. The manner in which the virus penetrates the tissues is not precisely known.

The possibility of wound infection must be conceded, although as far as the disease in cattle is concerned it cannot readily be proved. The presence of small cutaneous abrasions, no doubt, constitutes a means for virus entrance, and damage to the mucosa of the mouth incidental to dentition may likewise supply the virus with a suitable port of entrance.

In South Africa and other regions where apparently blackleg in sheep is not uncommon, the infection is introduced through the wounds occurring during shearing operations and as a result of castration and docking. In the former country, it is a common practice to dry hides removed from cattle in covered sheds which are also used to carry out sheep-shearing operations. In addition to this, the dry hides are frequently used to keep the sheep clean during shearing. A definite contact with contaminated material may thus readily come about and hence it is a common occurrence for the disease to break out on a relatively large scale, many cases developing in the sheep within a few days after the clip.

The bites of dogs may also be instrumental in inducing blackleg infection, especially if the canines have the opportunity of feasting on blackleg carcasses.

Although infection by ingestion can only exceptionally be experimentally induced, evidence tends to show that the virus may enter by way of the alimentary tract. Contaminated food and water constitute vehicles of infection. The fact that the virus is frequently present in the intestinal contents, the occurrence of a considerable number of cases in certain pastures and stables, as well as the presence of typical blackleg lesions in some of the internal organs are indications that the virus may have been introduced through the digestive apparatus.

Factors Favoring Infection.—In the establishment of a definite hazard of blackleg infection, one factor, above all others, plays a part, namely, locality. The disease has a marked regional distribution, and certain pastures and farms have, here and there, become notorious as permanent infection foci. It cannot be doubted that the inadequate disposal of blackleg carcasses, and the scattering about of virus with the dung of diseased as well as of normal animals, are largely responsible for the establishment of such centers. Yet, the occurrence of blackleg cases in recently settled regions, where cattle growing is a relatively new industry, may indicate that factors not now suspected have also been active.

Most of the blackleg cases occur during the pasture season, but it is probable that a seasonal influence, *per se,* does not especially increase the infection hazards. Grazing animals are most apt to come in contact with contaminated soil and vegetation, and as in many regions the rainfall is more profuse during the pasture season, there is warrant to believe that the foliage of forage plants is more liable to become soiled and that virulent soil particles will more readily remain adherent to its surface.

On the whole, the disease may make its appearance at any time, regardless of season. Wherever the virus exists in the soil, the development of the disease is not influenced by climate, season, weather or temperature in a manner worth considering. Even the influence of age may be more apparent than real. It is true that in districts where the disease habitually occurs, the young cattle of the ages between 6 months and 2 years furnish the great majority of the cases. However, blackleg is observed in younger as well as in older animals, and the author has witnessed outbreaks in which mature milk cows, from 5 to 9 years of age, succumbed to the disease in a most typical manner.

The fact that even the older animals originating in a blackleg-free area are apt to contract the disease when they are introduced

into a region where the disease is common, lends support to the belief that cattle inhabiting blackleg districts gradually acquire a degree of resistance based upon the presence of the virus in the alimentary canal.

It seems probable that the younger animals fail to contract the disease for lack of infection opportunities and that the older ones owe their relative safety to a measure of immunity acquired by the presence of bacilli which, for some reason, failed to exercise a pathogenic influence.

Epizootogical Considerations.—Blackleg is reported from most parts of the world where animal husbandry is an established industry. In some regions the losses may be slight, whereas in others the morbidity rate is relatively high. Before vaccination against blackleg was introduced into this country, and even now in unvaccinated herds, the losses occasioned by the disease were and are apt to amount to from 3 to 25 per cent of the young cattle in the affected districts. However, even in the face of the permanency of the infection sources, there are variations in the number of cases reported which cannot be readily explained.

In this country the disease is most common in the prairie states, although cases occur in nearly all the others. Only the southern Atlantic and eastern Gulf states appear to be somewhat exempt from blackleg outbreaks. The disease occurs in Canada, and from South America come reports of its frequent occurrence in the mountainous regions of Chile.

In Europe nearly all countries harbor the infection. It occurs in Japan and other parts of Asia, and both North and South Africa sustain losses caused by the disease. It is mentioned from Australia as causing losses among the cattle of Queensland and New South Wales.

Though quite universal in its distribution, the disease is more common in some districts than in others. In some countries the mountain pastures are particularly involved; in others, the fertile low lands furnish the greater number of cases. Wherever it has once made its presence known the disease is apt to occur again with a varying degree of morbidity.

Prophylaxis.—In any district where the disease has once established itself, the permanency of the virus in the soil practically compels cattle growers, and in certain regions, sheep raisers as well, to be prepared to face the blackleg problem each year anew. Under the circumstances in which the disease occurs, a final and complete

eradication of blackleg infection is not likely to be accomplished, and although this may not be an absolute impossibility, it would be folly to solely rely on measures having this end in view. It is essential that efforts to prevent a replenishment of infection sources be made, but the prophylaxis of blackleg will, perhaps for all time, in most affected districts, have to be directed to the mere prevention of losses among the species of livestock most apt to succumb to the disease.

It is, however, well within the range of possibility that measures commonly taken with that purpose in view may eventually reduce the morbidity rate to a vanishing point, even if it would be extremely hazardous to maintain that such a point had been definitely reached at any given time.

The practical solution of the blackleg problem, as it now exists, lies in proceeding as if the hazard of infection is a perennial one.

Elimination of Infection Sources.—In view of the durable form in which the virus persists in the soil, the elimination of the infection hazard associated therewith does not seem to offer a marked promise of success. In certain special cases, the improvement of land by subsoil drainage may become a factor in the reduction of infection chances, but such measures are applicable only in areas relatively insignificant in comparison with the extensive regions where the disease has to be reckoned with.

With other and more economical prophylactic means available, there is scarcely warrant for recommending soil amelioration for the purpose of blackleg control alone, but when by the same means the land may be rendered more productive from a purely agronomic point of view, it may be reasonably expected to become a factor also of sanitary value, and certainly so wherever blackleg enters into the problem.

If, in addition, measures are taken in order to prevent the development of new cases on such land, and if contamination is further guarded against by the exclusion of manure derived from infected animals, the infection hazard may be reduced. As a practical measure against blackleg, land improvement must, however, be regarded as being of a more or less subsidiary value.

Destruction of Virus.—On the other hand, the destruction of virus in its most accessible situation, the carcasses of animals dead with the disease, must be recognized as a sanitary measure of the greatest importance. The lamentable practice common on the cattle ranges of permitting such carcasses to decay on the surface has been no

small factor in rendering blackleg morbidity formidable in many districts.

Such carcasses should be destroyed by fire if at all possible, and preferably on the very spot where the animals succumbed. The carcasses should be placed on the fire intact without opening or removal of the hide. When burning is not possible, deep burial is the next choice, care being taken to deposit the contaminated surface soil with the carcass in the deepest portion of the pit.

The technical utilization of blackleg carcasses is permissible only when the nature of the equipment for its transportation, as well as the supervision of the rendering plant, are of such a nature that no virulent material can escape destruction.

The dung of diseased animals should be gathered and disposed of in the same manner. Thoroughness in the execution of this detail is probably more appropriate than the use of disinfectants, the value of which in connection with the prophylaxis of blackleg has always been more or less problematic. In fact, the flushing with an abundance of disinfectant solution may be more instrumental in the distribution of the virus than in its destruction.

The application of such a disinfectant as iodine to the wounds and abrasions incidental to sheep-shearing operations may, however, be recommended as a routine mode of procedure whenever blackleg infection can be feared.

Immunization.—The principal factor in the prophylaxis of blackleg is the protection of individual animals susceptible to the disease. Cattle and sheep belonging to this class should be removed from lots or pastures as soon as the disease has appeared among them. Prudence demands that such a precaution should always be taken, although the more effective preventive measure of immunization is the one upon which reliance must be placed.

As the methods of immunization have developed at the present time, there can be no doubt that their adequate application will bring more or less complete control of blackleg well within the range of possibility. Even if immunization has the disadvantage of being a perennial chore, it is certain that by this means, and by this alone, blackleg losses can be eliminated with a marked degree of success.

Up to a relatively short time ago, the establishment of immunity to blackleg was brought about by the injection of vaccines in which the living bacilli or their spores had been subjected to attenuation, usually secured by exposure to heat for varying periods. On the whole, the results obtained were favorable, and the use of so-called

spore vaccines cut down the losses among susceptible animals to about 1 per cent. However, disappointment was occasionally experienced and vaccination results were not always satisfactory.

Practically all living vaccines have a common disadvantage: it is difficult to stabilize the degree of attenuation owing to variations in the virulence of the organisms used in the preparation of the vaccines. A further factor of uncertainty is the difference in the degree of susceptibility of the animals to be inoculated.

The range of virulence between an effective vaccine and an ineffective or even dangerous one was too narrow; cases occurred in which either the vaccination actually caused vaccination blackleg or a later development of the disease showed that a desirable degree of immunity had not been established.

It was subsequently shown that, after all, the immunizing quality of a spore vaccine was not due to the organisms *per se,* but to the presence of the so-called aggressins in the muscle tissue from which the powdered or other forms of spore vaccines were prepared.

Blackleg immunity thus depends on the development of anti-aggressins and is apparently not dependent on the formation of either antitoxic or antibacterial antibodies. For this reason, the use of spore vaccines has been largely abandoned and in actual practice has been replaced by that of natural or artificial aggressins or filtrates.

Natural aggressins consist of the edematous fluid and juices obtained from the affected, heavy muscle masses of artificially infected cattle. By centrifugation and filtration the blackleg organisms and their spores are removed and a preservative is added to the fluid in order to assure its keeping qualities.

Blackleg filtrates or artificial aggressins are prepared in a similar manner, but instead of affected tissues, cultures of the blackleg bacillus *in vitro* are employed for their preparation.

Aggressins, natural as well as artificial, have the advantage of complete safety in use, combined with a high immunizing value; and the immunity they induce is a lasting one. They fulfill all the requirements of a good vaccine, and field reports pertaining to several hundred thousand head of cattle treated with natural aggressin show that less than 1 in 10,000 animals injected later became affected with the disease, and that the same results were obtained by the use of blackleg filtrate or artificial aggressin.

The establishment of an active immunity against blackleg by the use of aggressins or filtrates constitutes the principal means of de-

fense against the inroads of the disease, but a passive immunity by the injection of antiserum may also be conferred, and under special circumstances the use of the latter is clearly indicated. Such a serum is prepared by the hyperimmunization of animals with either virulent cultures or with germ-free filtrates.

In common with other antisera, blackleg antiserum confers a typical, passive immunity immediately available, but of transient character, usually vanishing within a period of 2 weeks. By its use, outbreaks may be checked within 12 to 25 hours.

In regions where blackleg is more or less enzootic, the susceptible animals should be immunized each year. There are apparently some differences of opinion in regard to the age of the animals at which this should be done. However, there is agreement in this, that a calf should certainly have been treated when it is 6 months old. Nevertheless, calves may be vaccinated at any age, and it is a sound practice to treat them when at pasture with their dams, in the early fall.

In badly infected pastures, it is advisable to treat them when they are only 3 or 4 weeks old, but a second vaccination of such animals is recommended when they are between 5 and 8 months old. Some authorities go so far as to recommend a revaccination 6 weeks after the first one, of any calf which was treated when younger than 6 months, and in the event of its still being below that age at the time of its second vaccination to treat it once more if the animal be particularly exposed to infection. As a rule, a calf vaccinated when older than 6 months requires no further protection.

When dealing with animals occupying pastures in which the disease has already broken out, it is important to remember that a full immunity from the use of filtrates or natural aggressins cannot be established until after a period ranging from 3 to 10 days after its injection. In some instances, there were even indications that the injection of the immunizing substances under the conditions mentioned was followed by an increase in blackleg morbidity. Hence it is advisable that the susceptible animals be immediately protected by the use of blackleg antiserum, and that this treatment be followed from 8 to 12 days later by the customary aggressin or filtrate injection.

Owing to the fact that blackleg is less apt to affect sheep than cattle, a routine vaccination of the former is not usually practiced. On ranges where blackleg in sheep is more or less common, their treatment may, however, be systematically undertaken with profitable results. In actual outbreaks which follow docking or shearing

operations, serum injection, later followed by vaccination, is the proper method of procedure.

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CHAPTER XXV

MALIGNANT EDEMA

Malignant edema is the name first used by Robert Koch to designate a highly characteristic, acute wound infection, marked by inflammatory, edematous tumefaction, by emphysematous phenomena and by gangrenous changes within and of the tissues involved. The disease is of microbic origin, the causative organisms being anaerobes belonging apparently to a more or less closely related group, which ordinarily exists under purely saprophytic conditions.

The subcutaneous connective tissues, fasciae, the skeletal muscles are the parts most frequently involved, and the serous cavities may become readily invaded by the virus. More rarely the infection has its primary seat in some of the internal organs. Malignant edema is nearly always associated with some form of traumatism, marked by a rapid course, by evidence of a profound intoxication and by a high mortality rate.

It is a relatively rare disease, although under special circumstances several cases may occur in certain groups of animals. There is evidence which shows that it was more frequently observed during the era which preceded the introduction of antiseptic surgery.

The Virus of Malignant Edema.—The disease clinically and pathoanatomically recognized as malignant edema apparently does not constitute a strictly specific unity among the infectious diseases inasmuch as several anaerobic organisms have been indicated as etiologic factors. They include the *Vibrion septique* of Pasteur, the *Bacillus oedematis maligni* of Koch as well as the organisms described by Ghon and Sachs, by Fraenkel, by Welch and Nutall, by Novy, by Veillon and Zuper, and others. These organisms are probably closely related members of a distinct group of anaerobes; some described as specifically separate may be merely varieties of the same species.

The *Vibrion septique* is the type most commonly described in connection with malignant edema, and as far as its general pathogenic behavior and occurrence in nature are concerned this organism does not differ greatly from the other members of the group; however, they may vary in their purely bacteriologic peculiarities. They are all spore-forming anaerobes, capable of toxin production.

Aside from the affected tissues of the animals suffering from the disease, it is commonly found in putrid substances, in feces, and above all in the upper strata of the soil, in regions which have been under intense cultivation for long periods. Such soils, as well as the water which drains from them, constitute the most common source of infection.

In the tissues of the affected animal, the organisms invade new areas by mere growth. Up to a certain stage the infection remains somewhat localized; but soon after death the bacilli rapidly permeate all parts.

The spores are exceedingly resistant to most influences by which the vegetative forms of the bacillus are readily destroyed. When contained in dried muscle material or in hermetically sealed edematous fluid, they proved to be virulent after many years of storage. The spores are but slowly killed by direct exposure to solar radiation, and drying does not influence their virulence. In polluted soil the pathogenic properties of the spores are preserved for an indefinite period, and when contained in the surface water collecting on such soils, their virulence was found to be intact for several months.

Bacilli without spores are readily destroyed by exposure to moist heat at 100° C., but the spores require a 10 to 15 minutes' exposure to a temperature of 120° C. for their destruction.

The resistance of the spores to the action of chemical disinfectants is very marked; even contact of from 24 to 48 hours with solutions of mercuric chloride (0.05 per cent), phenol (3 to 5 per cent) and with alcohol (90 per cent) was not sufficient to kill them. On the other hand, exposure for 48 hours to a solution of permanganate of potash (2 per cent) and of nitrate of silver (0.2 per cent) destroyed them. The action of heated disinfectants is more energetic.

Host Species.—Owing to the fact that the classically clinical phenomenon to which the name malignant edema has been given may be caused by a number of anaerobic microbes either related to one another or not, it is difficult clearly to define the host species for each at this time. In the various animal species, there may exist differences in the degree of susceptibility to each microbic species or strain which as yet are not clearly defined.

Most of the cases of malignant edema are probably due to the malignant edema bacillus (*Vibrion septique*) or to its varieties. To these the horse appears to be most liable, and this susceptibility is equaled by that of man. The bovine species are less susceptible, although natural infection through trauma of the genital tract in the course

of parturition is frequently mentioned in literature and there designated as "parturient blackleg."

In sheep as well as in swine the susceptibility is nearly as marked as in the equine species, and under special circumstances (shearing, operations, subcutaneous injections) many animals belonging to these species may simultaneously become infected.

Experimentally, malignant edema may be induced in cavias, rabbits, white and gray rats, mice, fowls and pigeons, but artificial infection is not readily brought about in goats, dogs, cats and ducks.

Modes and Vehicles of Infection.—Malignant edema is, above all, a wound infection. It has been found to occur after a considerable variety of accidental wounds of the skin and mucous membranes. Punctured wounds, nailpricks, traumatism in connection with shearing operations, skin damage caused by saddles and harness, tears incidental to parturition have served as entrance ports for the virus. Wounds of war, especially those inflicted by shell fragments, have always been notorious in this connection.

Surgical wounds, in the pre-antiseptic days, often admitted the virus, and even now it is occasionally observed after castration, docking, subcutaneous injections, vaccination and, formerly, as a sequel to roweling, when this was a fashionable part of veterinary surgery.

The virus is introduced by means of particles of soil, fecal matter and other filth from the surface of the skin; unclean surgical instruments and contaminated injection materials or wound dressings have also proved to be potent vehicles of mischief in connection with malignant edema.

The disease is characterized by a brief period of incubation; it usually declares itself within from 12 to 36 hours after introduction of virulent material. Malignant edema following parturition in the bovine manifests itself in from 2 to 5 days after this act.

Factors Favoring Infection.—A considerable volume of evidence indicates that any form of traumatism may permit the entrance of the virus of malignant edema and its pathogenic action, but the latter may be materially influenced by a number of factors.

Recent wounds are most apt to serve as the port of entrance of the virus, and when the process of repair by granulation is progressing the infection chances become correspondingly reduced. Wounds which bleed freely are also less suitable for the penetration of the organisms. Deep wounds in regions having an abundance of connective tissue and accompanied by contusion, laceration and the trituration of tissues are particularly favorable to the development of ma-

lignant edema. Crushed muscle tissue, above all, seems to constitute an optimum soil for the bacilli.

The presence of extravasated blood or lymph within the damaged parts favors the growth of the virus and the exercise of its vital functions. The more the circulation of the parts has become stagnant, the more the supply of oxygen is suppressed, the better the conditions for growth and the display of pathogenic action.

An adequate and uninterrupted blood supply to the damaged parts is a formidable means of defense, while on the other hand, the penetration of the virus in a medium deprived of oxygen, such as tissues in a state approaching gangrene, furnishes an excellent condition for the development of the disease.

The simultaneous introduction of the virus into the tissue with particles of soil, granules of sand, or other foreign bodies and substances is quite conducive to pathogenesis. Particularly favorable to the latter is the presence of aerobic microbes, saprophytic as well as pathogenic, and in all probability this factor plays a most essential part in the causation of malignant edema.

Pathogenesis is further dependent on the production of toxins by the causative organisms. The toxins paralyze the defensive powers of the tissues by the exercise of a negative chemotactic influence, and in some way toxin formation is particularly favored by the conditions mentioned above.

Prophylaxis.—Because of the relatively rare occurrence of malignant edema, a systematic practice of prophylaxis is felt to be less urgent or necessary than in some of the other transmissible diseases of livestock in which a formidable morbidity rate supplies an incentive to constant and beforehand vigilance. In a general way, the prevention of malignant edema is included among the measures which render operative surgery safe against all hazards of a microbic nature as well as among those which are part of the rational management and treatment of accidental wounds. Only where the repeated occurrence of the disease is an indication of an extraordinary infection risk should the advisibility of efforts looking toward the establishment of immunity be given consideration.

The Management of Traumatisms.—Constant and adequate antiseptic treatment of accidental wounds and aseptic surgery form the proper basis of the prophylaxis of malignant edema. Non-surgical traumatisms must be managed in accordance with the rules of antiseptic wound treatment, which should certainly include the removal of foreign substances, clots of blood and tissue débris.

In operative procedures, asepsis must prevail, and even in the performance of such simple operations as subcutaneous injections, vaccination and the like, this detail must not be neglected. Not only should instruments and dressing materials be sterile, but the skin surface should be cleansed and sterilized likewise. In the vaccination or serum treatment of swine, caution in this regard is particularly imperative. The development of malignant edema in swine after immunization against hog-cholera is by no means an uncommon catastrophe, and this is largely due to lack of surgical cleanliness.

The fact that the spores of malignant edema organisms are extremely resistant to the action of disinfectants does not in the least render antiseptic precautions superfluous, because the influence of the microbes commonly associated with wound infection is quite probably as much a factor in the development of the disease as the specific organism of malignant edema itself.

Immunization.—Immunization as a prophylactic measure against malignant edema has thus far not become an established practice. The relatively rare occurrence of the disease, combined with the fact that there is as yet no method of immunization approved by continued application, is responsible for a certain disregard of its possibilities.

Nearly all the evidence pertaining to the immunization against malignant edema is of an experimental nature. This evidence indicates that an efficient filtrate can be prepared by following the same methods used in the preparation of blackleg filtrates, but the fact that such malignant edema filtrates are apt to possess markedly toxic properties should not be overlooked.

It was also shown that it is possible to prepare an antiserum capable of conferring protection against previous or simultaneous inoculations with virulent material. The use of antiserum, harmless in itself, may be indicated in the case of wounds particularly apt to admit and to propagate the virus or in regions in which the disease is to be especially feared.

The use of mixtures of toxin and antiserum has likewise been the subject of experiment. The latter showed that a single dose of such a mixture did not produce an immunity sufficient to protect against a fatal dose of culture after an interval of two months. However, two such injections proved to be effective for the purpose up to five months at least. The period elapsing between the two injections should be about two weeks, although a reasonably strong immunity is produced when the interval between the two immunizing doses is as short as only one week.

On the other hand, a report of failure to secure an experimental active immunity by the use of filtrates or of diluted cultures indicates that immunization against malignant edema may not yet have advanced beyond the experimental stage.

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CHAPTER XXVI

BRAXY

BRAXY or bradsot is an acute or peracute infectious disease of sheep, occurring in Scotland, Ireland, Cornwall, the Shetland Islands, Norway, Iceland, and the Faroe Islands. It has also been described from Germany (Mecklenberg, Pomerania, the Province of Saxony), and disorders very closely related to it have been observed in Tasmania, New Zealand, New South Wales and Victoria.

In the Northwestern European centers of infection it occurs in its most classical form. There it is marked by a peracute course, death occurring from two to twelve hours after the initial signs of illness. Its most characteristic lesions are found in the abomasum, the mucosa of which is edematous and hemorrhagically infiltrated, a condition in which other portions of the intestinal canal may participate. A marked degree of toxemia is a common feature of the disease, and the parenchymatous organs, notably the kidney, become severely damaged. In the braxy-like affection of sheep in New South Wales, where it is known as "black disease," the primary lesions are to be found in the liver and consist of circumscribed areas of necrosis.

Braxy has a decidedly regional distribution and seasonal incidence. In Scotland, and in the Scandinavian countries, it is principally a pasture disease, whereas in Germany it is more apt to show itself in stable outbreaks.

It is practically always fatal, and in some regions it accounts for enormous losses among the sheep. In some of the affected areas of Scotland, the morbidity rate ranges between 15 and 20 per cent, and on certain farms, particularly known as braxy foci, a loss of 20 to 25 per cent is only a moderate average. In one section the loss is estimated at from 45 to 50 per cent, and on certain farms in the West Highlands, the disease has been known to wipe out the whole stock of lambs.

The Virus of Braxy.—The specific cause of braxy is an anaerobic bacillus, motile, and spore-forming. It is designated as *Bacillus gastromycosis ovis.* This organism, though not identical with, closely resembles the blackleg bacillus and is regarded by at least one

authority as identical with Pasteur's *Vibrion septique.* It is by no means impossible that, as in the case of malignant edema, a number of closely related organisms may serve as etiologic factors in braxy. Immunological evidence, however, indicates that so far as the Scandinavian and Scottish forms of the disease are concerned, the *Bacillus gastromycosis ovis* constitutes the principal causative agent.

This organism occurs in pure culture in the diseased portions of the gastro-intestinal mucosa, and in the edematous submucosa it is frequently found in enormous numbers. It is also present in the serous cavities of animals dead with the disease. The bacillus does not sporulate in the peritoneal fluid of sheep killed while suffering from the disease, but in animals found dead with braxy the organisms had formed spores in abundance.

The braxy bacillus is apparently capable of producing a toxin, although in cultures toxic substances can only be shown to be present in small amounts.

The organism is probably a facultative parasite, and all available evidence tends to show that, like other pathogenic anaerobes, it is especially to be found in the upper soil strata, and that it is introduced into the digestive organs with the feed.

Host Species.—Under natural conditions, braxy is a disease confined exclusively to sheep, and nothing is known of its spontaneous occurrence in other animal species. Cultures of the organisms are pathogenic not only to sheep, but also to calves, pigs, cavias, fowls, pigeons, rats and mice, when experimentally inoculated into these animals.

Modes and Vehicles of Infection.—In the light of a great volume of empirical knowledge accumulated in the course of a long period, an alimentary origin of the disease cannot be doubted. The braxy bacilli or their spores, scattered in the soil, are ingested with the food. The port of entrance in the majority of the cases is probably furnished by the abomasum, but the possibility of tissue invasion in other parts of the alimentary canal cannot be excluded. There is no evidence of contagion. There is, however, no information on the mode of infection, based on facts experimentally revealed.

Apparently sheep cannot be infected by feeding them with the bacilli, although subcutaneous inoculations readily produce a blackleg-like edema and hemorrhagic infiltration of the muscles.

As in blackleg, the pathogenesis of braxy is probably a more or less complex process, which requires the presence of some contributing factor before the bacilli can display their full disease-producing qualities. This factor may have the nature of an aggressin or of a toxin, which

after absorption impairs the defensive power of the tissues. It is not known whether such substances occur in the decaying vegetation of braxy pastures or from the ingestion of the organisms in the digestive organs.

Factors Favoring Infection.—Not only is braxy to be found within rather well-defined geographical limits, but in areas where the disease is more or less enzootic, there are differences in the infection hazard associated with the various pastures. Like other diseases due to spore-forming organisms, infection with braxy is to a large extent a matter of locality. Within the affected areas, the disease is most commonly observed on old grazing pastures in hilly districts, where badly infected and dangerous pieces of land often lie side by side with relatively safe pastures.

In Norway, braxy does not occur on the mountain pastures, but breaks out among the sheep when about the middle of October they are taken to the smaller home pastures. It is probable that the practice of slaughtering and skinning of affected sheep in the winter quarters is in a large measure responsible for the establishment of such infection centers. The practice of feeding the meat of braxy carcasses to shepherd dogs contributes, no doubt, to the extension of such infection centers.

The seasonal factor is as influential in the occurrence of braxy as the regional one. The disease occurs almost exclusively in winter, from October to January, and is most destructive in November, when sudden changes from mild weather to cold are common and when rainy days are succeeded by frosty nights. Many observations indicate that hoar-frost is particularly to be feared.

The age of the sheep exercises a marked influence on their susceptibility to braxy. Vigorous young animals from one to two years old are particularly susceptible. This is especially true in the braxy districts of Great Britain and Scandinavia. On the other hand, as the disease is seen in Germany it appears that older sheep are also apt to succumb to it.

Lambs following their dams are relatively exempt from braxy, but after weaning time the susceptibility steadily increases and reaches its climax in late autumn and early winter. It has been pointed out that in infected districts but very few sheep escape the disease. Most of the cases are mild enough to make its detection impossible, and it is thought that these non-fatal forms of the disease account for the resistance shown by older animals.

The breeds of sheep native of braxy-infested districts are more re-

sistant to the disease than imported animals. In certain Norwegian districts the disease became epizootic only when attempts were made to improve the native breed by crossing with more refined, imported stock. In such flocks, the disease, with great accuracy, selects the better and more highly improved animals, while the old, native breed frequently escapes on account of its resistance acquired in the course of time.

Prophylaxis. *General Measures.*—Although it is apparently futile to make an impression on the ever-recurring outbreaks in the affected areas, by general hygiene or sanitary measures, it is, nevertheless, apparent that certain details of flock management may tend to mitigate the losses. At least, empirically acquired knowledge tends to indicate that it is wise to take the lambs to their winter pasture early in the season, about the latter part of August or the beginning of September. Susceptible sheep handled in this manner apparently incur less hazard from braxy than the ones taken down later in the season. Whether the animals are slowly immunized by the ingestion of more or less inadequate virus present in the forage, or whether lambs removed to winter pastures shortly after weaning had acquired a passive immunity through their dam's milk, is a matter of speculation, but apparently the precaution is worthy of consideration.

A further precaution is the avoidance of young grass or other foliage after a hoar-frost; also the feeding of dry roughage or concentrates, either as a supplement to or as a substitute for a pasture régime, has been deemed advisable by competent observers. In a disease so manifestly of alimentary origin, the part played by the food itself cannot be neglected, and in this connection it is significant that the greatest incidence of braxy is peculiar to the season when a maximum amount of decaying vegetation is available to the sheep.

As with other diseases due to spore-forming organisms, the adequate disposal of braxy carcasses is imperative as a measure of precaution, and prudence demands that the meat of such animals shall not be used as food by shepherd dogs.

Immunization.—If the various aspects of the braxy problem are carefully examined there can be but little doubt that an adequate solution must be sought for in the establishment of an artificial immunity of sufficient duration to afford protection to sheep of the susceptible ages. It is not surprising that many attempts in that direction have been made.

Before considering immunization methods based upon those found

to be useful in other diseases, mention must be made of a curious preventive treatment practiced by flock masters in certain parts of Scotland. Suggestive of the medical methods of ancient China and those of the Middle Ages, the method could be disregarded were it not for the testimony of its effectiveness by competent and trustworthy observers.

It is known as the pig dung treatment and consists of the following procedure. An aged pig is put to grass on a braxy pasture for three days, and while there is given as much skimmed milk as it will consume. The dung of the pig is collected as soon as voided and 1 pint of it mixed with 15 pints of milk. The mixture is strained through muslin and is then ready for use. The sheep to be treated are fasted for 12 hours and a wine-glass full of the mixture is given to each animal. This should be done about the third week of September (Mellon).

The treatment has been adversely criticized because the treated animals are apt to become somewhat unthrifty, but the fact remains that it has been proved to be efficient enough to permit sheep farming to be carried on in regions where this would have been almost impossible without it.

Its *modus operandi* is not known and remains a subject for speculation. Apparently it brings about a more or less effective protection of animals treated. Whether this comes about by the acquisition of immunity or through the action of a specific bacteriophage has not been determined.

The first efforts at immunization based upon rational principles were made by Neilsen, who prepared a vaccine composed of powdered, dried kidney of infected animals. At first some favorable results were obtained after its use, but later on the occurrence of vaccination braxy caused the method to be abandoned.

Satisfying results were also obtained with a suspension of dried bouillon culture containing spores, but like the use of threads impregnated with material containing spores, the method failed to prove acceptable in practice.

More successful was the sero-vaccination, devised by Jensen. This consists of the subcutaneous injection of a mixture of braxy culture containing living spores and braxy antiserum. The immune serum is derived from horses immunized by means of increasing doses of fresh bouillon cultures of the braxy bacillus. The serum is dried and powdered, and in this condition it will keep active for years.

For the culture one is chosen which contains a large number of

spores. This is also thoroughly dried and powdered, but must be freshly prepared every year.

The sheep to be immunized are inoculated in autumn; for this purpose the serum-culture mixture is placed in sterile water and injected subcutaneously. The results obtained with this method of vaccination in Iceland and the Faroe Islands were quite satisfactory, and in a trial made with it in Scotland, it was possible to reduce the fatalities by about two-thirds.

Another method of vaccination is described by Mellon. For the preparation of the vaccine the peritoneal fluid of an animal just dead of braxy is collected in sterile pipettes. These are then incubated for 12 hours at 37° C. Flasks containing glucose broth, covered with olive oil, are sterilized by heat, the contents of the pipettes are carefully added to the broth and the whole is heated to 80° C. for twenty minutes in order to kill any accidental non-sporing organism.

After incubation for 24 hours, an abundance of dense clumps of light grayish growth settles to the bottom of the flasks, and this, if found to consist of a pure culture of non-sporing organisms, constitutes a first vaccine. A similar culture incubated for 36 hours is used as a second vaccine.

This process is carried out with four lots of peritoneal fluid collected from braxy cases occurring in different parts of the affected areas, and the vaccines so obtained are mixed together before use.

The vaccine must not be used later than September 21 or some of the vaccinated sheep will succumb as a result. By its use the mortality of braxy according to Mellon never exceeds 1 per cent even in badly affected districts.

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CHAPTER XXVII

TETANUS

TETANUS, or lockjaw, is a disease caused by a micro-organism capable of producing a toxin having a specific affinity for the central nerve centers, motor centers especially. The intoxication brings about tonic muscular contractions which give rise to local or general rigidity, usually accompanied by increased reflex irritability. It causes death by the asphyxia which follows the fixation of the respiratory mechanism.

The geographic distribution of the disease is in a large measure determined by climatic influences. It is uncommon in regions having a low, mean temperature, but throughout the temperate zones it occurs sporadically with varying degrees of frequency. In semi-tropical and tropical countries the incidence of tetanus is much higher, and in certain regions it actually assumes an enzootic character.

The occurrence of the disease, even in regions where it is habitually present, is subject to marked fluctuations. In the course of certain seasons the cases may be very numerous, whereas at other times the morbidity rate may show a pronounced reduction in the same environment. In many countries there are certain localities in which the disease is particularly prevalent.

Essentially a wound infection, the incidence of tetanus has been beneficially influenced by the introduction of aseptic surgery and antiseptic wound treatment. Post-castration calamities through the development of lockjaw, for instance, have become uncommon since the use of "clamps" made way for a more rational surgical technique.

Tetanus is always accompanied by a high death-rate for all animals affected. In horses it ranges between 45 and 90 per cent; in young animals, such as colts and lambs, the mortality is frequently not less than 95 or 100 per cent. In the non-fatal cases the period of convalescence is usually a long one, from 5 to 8 weeks being involved in the process.

Susceptible Species.—All the domesticated animal species are susceptible to tetanus, but in varying degrees. Horses are most liable to the disease, and it has been experimentally shown that the relative

susceptibility of this species is about 12 times greater than that of the mouse, although even the latter is extremely sensitive to the toxin.

Tetanus is not uncommon in goats and sheep, but is less frequently seen in cattle. In the latter, cows and calves furnish most of the cases. In swine, the disease is occasionally seen, but it is relatively rare in the dog and its occurrence in the cat is quite doubtful. All forms of poultry show a marked resistance to tetanus infection.

Laboratory animals, such as mice, white rats, cavias and rabbits, can be readily infected, but the cold-blooded animals are quite refractory.

The Virus of Tetanus.—The causative factor of tetanus is the *Bacillus tetani*, a spore-forming anaerobe. This microbe is widely distributed in nature, although the distribution of the disease does not in all cases correspond with the more or less ubiquitous presence of its virus.

The latter is apt to be present in soil, in water, in street dust, and on vegetation soiled with earth. Soils rich in organic materials are most liable to harbor the bacillus. The organism passes through the alimentary canal without alteration and can be readily recovered from the feces as well as from the intestinal contents. It is common in stable manure and on stable floors or in the materials used in their construction. Well-manured garden soils are extremely rich in virulent materials, especially in regions where for long periods intensive cultivation has been practiced.

The formation of the spherical, highly resistant spores takes place readily under the ordinary conditions in which the microbes exist in nature. The organism, occurring as a saprophyte, appears to be capable of reproduction under certain, as yet, undefined conditions relating to humidity, temperature, or the composition of the ambient mediums in which it may be found. When the conditions for growth and multiplication become less favorable, the spores assure the survival of the generation thus formed.

In connection with the pathogenesis of the disease, the capacity of the tetanus bacillus to form the specific exotoxin is its most important character. This highly toxic bacillary product is a true antigen as well, and introduced into the animal body it induces the latter to form specific antibodies.

The tetanus organism is very resistant to most external influences, and this quality is entirely associated with the spores. Their resistance to heat is not excelled by that of any other pathogenic microbic species. Contained in a liquid medium within a closed vessel

the spores are not affected by a temperature of 80° C. acting for 6 hours. They endure exposure at 90° C. for 2 hours, but when the medium is heated to 100° C. they survive only from 3 to 5 minutes.

Within the substance of the soil, where they are sheltered against the action of the air and light, the spores remain viable at least for 1 year and most probably for a much longer period. They remain alive in water, clean as well as polluted, for long periods, and drying has little or no effect on them.

Light has a slowly destructive action on them, and they may be killed by an exposure to diffused daylight lasting from 1 to 2 months.

In putrefactive material the spores survive for indefinite periods, and the dissolved substances of the soil do not alter their viability or their virulence.

The dried pus from a tetanus-infected wound was found to be still virulent after storage of 16 months, and old castration clamps caused the disease after 18 months even after they were boiled in water for 5 minutes.

The spores are also extremely resistant to the chemical substances commonly used as disinfectants. Silk threads in which the spores were incorporated were still virulent after an immersion for 10 hours in a 5 per cent phenol solution, but the virulence had been destroyed after a similar treatment during 15 hours. The addition of 0.5 per cent hydrochloric acid hastened the destruction of the virus, which became inactive after an immersion lasting 2 hours. The destructive action of the cresols was no more pronounced than that of phenol.

If exposed for more than 3 hours in a 0.1 per cent sublimate solution the spores are apt to succumb, but the addition of 0.5 per cent hydrochloric acid shortens the surviving period to 30 minutes.

The spores resist submersion in chloroform in 2 days, and they are not injured in absolute alcohol or in a watery dilution of the same. They withstand the action of a 1 per cent solution of silver nitrate up to a hundred minutes' exposure and of 0.1 per cent solution for 24 hours.

More destructive to tetanus spores is hydrogen peroxide, a 30 per cent solution of which killed them in 5 minutes. A 1 to 2 per cent solution rendered them harmless in 24 hours, and a 3 per cent solution in 2 hours. A 0.4 per cent solution of chlorine destroyed the spores in 5 minutes and a 0.003 per cent solution in 1 hour. A 0.5 per cent Lugol's solution of iodine required 80 minutes to kill

the spores, and a solution of twice that strength 1 hour. A 10 per cent tincture of iodine destroyed the spores in 10 minutes.

Formalin in a 30 per cent solution killed the spores in 40 minutes, and 24 hours were required for a 3 per cent solution to accomplish the same purpose.

The virulence of spores kept in glycerin or in olive oil was preserved for more than 17 months.

It is quite evident, thus, that none of the disinfectants in common use can be regarded as effective in a space of time suitable for practical purposes. An instantaneous killing is not brought about by any of the disinfectants ordinarily used.

The disinfecting agents which act by oxidation, such as halogens and hydrogen peroxide, have the more marked killing powers, but those which coagulate albuminous materials, such as alcohol, the heavy metals, phenol and the cresols, have a more feeble action or fail to destroy the spores altogether.

The tetanus toxin, on the other hand, is quite fragile. It is thermolabile and is markedly attenuated after 40 minutes' heating at 60° C. or after 20 minutes at 62° C. Its toxicity has completely disappeared after a 30-minute exposure to 65° C.; it gradually disappears when the toxin is exposed to the air, and in the presence of light this destructive action is substantially hastened.

Modes and Vehicles of Infection.—The *modus operandi* of tetanus infection is that an exotoxin produced by the specific microbe finds its way to certain nerve centers with which it combines. What reaction takes place between it and the neuron protoplasm is not known at this time.

The first phase of the pathogenic process is the introduction of spores or bacilli into the tissues, and, probably in all cases this results from traumatism. The wounds which admit the infection may not be detected on account of their size or location, or they may have healed before the disease manifested itself, but it is safe to assert that tetanus always results from wound infection. All types of wounds involving the skin or any of the mucosa may serve as an entrance to the spores, and the stump of the umbilical cord of the new-born may do likewise.

The virus may be introduced at the time the injury takes place, or the infection may enter at a later period. Foreign bodies soiled with earth entering the soft parts are particularly apt to serve as vehicles for the virus, and contamination with stable manure is a formidable source of lockjaw infection. Punctured wounds of the

feet, infected castration wounds and even superficial abrasions exposed to the dust of the fields and of the streets are commonly the source of a subsequent development of the disease.

In cattle, most of the cases of tetanus are post-parturient, the virus having been introduced into wounds and lacerations of the uterus or the vagina incidental to difficult partus or caused by the maladroitness of those who render assistance. Some observations seem to indicate that such persons have conveyed the infection from animal to animal.

Tetanus of the new-born, especially apt to occur in colts and lambs, comes about through the infection of the umbilicus, and in tetanus territory this form of the disease is to be particularly feared.

Contact infection does not occur; the bacilli which cause the disease are practically always derived from the soil, stable manure or similar substances.

Although there are indications that toxin adhering to the spores originating outside of the body may cause the disease, it is generally accepted that it forms in the tissues. The latter in a normal state may not be a specially suitable soil for the bacilli to multiply in, but under the influence of tissue damage, of subsequent pyogenic infection or of foreign material introduced, the growth of the bacilli is substantially promoted.

Necrotic tissue and extravasated blood are very suitable for the germination of the spores, the multiplication of the bacilli and the formation of the toxin.

The organisms remain localized at the original site of the infection, and during the life of the animal they are never encountered in the circulating blood or in any of the organs. On the other hand, the toxin which they produce is readily absorbed and rapidly diffused by the circulation.

Thus, although the blood remains sterile during the course of the disease, it commonly contains the toxin in appreciable amounts. This was successfully shown by the inoculation of mice with the blood taken from man or animals suffering with the disease. This toxicity of the blood was shown in a striking manner in an outbreak of tetanus among children which occurred in St. Louis in 1902. The toxin was identified in diphtheria antitoxin with which the children had been treated, and it was proved by a commission that the horse which yielded the serum was in the incubation period of the disease.

Tetanus toxin is absorbed only when directly introduced into the tissues, but when it is administered *per os,* even in massive doses, it

produces no harm and appears to be readily destroyed by digestive action. It has a specific affinity for nerve tissues, and contained in the blood or the lymph it reaches the central nerve centers through absorption by the end plates of the motor nerves. There is good experimental evidence which shows that it is conveyed by the nerve paths only and that it does not penetrate the nerve cells directly from the blood or the lymph.

In spontaneous infection the period of incubation ranges, as a rule, between one and three weeks, although in young animals this period may be materially shortened. Longer incubation periods have been observed, and in such cases there is reason to suspect that the spores may have been retained in a scar or in a pus focus where, for the time being, conditions suitable for germination were not present.

It is not impossible that, in the cases in which tetanus develops more than once in a given animal within a relatively short space of time, such a spore retention was accountable for the repeated attacks.

The length of the incubation period is apparently determined by the amount of the toxin absorbed and probably also by the length of the path to be traveled by it between the site of infection and the central nervous system.

Factors Favoring Infection.—Aside from the specific susceptibility shown by various animals toward tetanus intoxication, the factor of age, at least in some species, seems to favor the infection. As a rule, young animals are more liable to lockjaw than older ones. This is quite true of colts and lambs and in tetanus regions, where infection through the navel wound has given rise to regular outbreaks.

The susceptibility to tetanus does not seem to be reduced by a previous attack of the disease, and cases have been observed in which horses became affected two or three times in the course of one year.

The nature of a traumatism materially influences the infection hazard. The more dangerous wounds in this respect are punctures soiled with earth, manure and like materials. Nail punctures of the foot are very formidable sources of danger, and post-parturient infection must also be given consideration.

Contused and lacerated wounds are favorable ports of entrance for the virus, and all suppurating wounds, even the superficial ones (harness and saddle-sores), are to be regarded as suitable for the development of the specific microbe.

Positive infection is further enhanced by the presence of foreign bodies (castration clamps, splinters, shell fragments) and most certainly by the simultaneous introduction of aerobic bacteria especially

of the common pus producers. These always find in the tissues the condition most suitable for their growth; they cause the damage which favors the germination of the spores and the production of toxin. A most ideal condition for the development of the tetanus bacillus exists when it is accompanied by pyogenic organisms under a protecting scab. In all probability, the fact that the anaerobic tetanus bacillus may grow under aerobic conditions when accompanied by the oxygen-consuming pyogenic microbes may account for the influence exercised by the latter.

Prophylaxis.—The prophylaxis of tetanus differs in some respect from that of other diseases. Both the nature of the disorder and the limitations of the present preventive technique help to account for such differences. Even in regions where lockjaw is more or less enzootic, the morbidity rate is low enough so that in comparison with other infections its economic importance is not severely felt. It never assumes the proportions of a mass disease or of a major scourge.

The fact that the disease is caused by a more or less ubiquitous microbe of the soil added to the thus far insurmountable difficulty of securing lasting active immunity has limited prophylactic measures merely to those individual animals which are particularly endangered. They are the ones which were subjected to surgical or obstetrical intervention and which sustained a traumatism.

Wound Management.—The improved surgical technique of the post-Listerian period pertaining to operative as well as to wound surgery has more than any other factor contributed to the successful prophylaxis of tetanus. Hence the more adequate management of wounds as well as pre-operative asepsis or antisepsis are still to be regarded as the most efficient measures of prevention.

The value of perfect asepsis is obvious, and even the high degree of resistance shown by the tetanus spores to the action of disinfectants, as related above, does not in any way detract from the efficacy of antiseptic wound treatment, This, combined with such surgical details as drainage and the removal of tissue débris or foreign materials, tends to deprive the tetanus spores of the symbiotic aid of the various aerobic organisms upon which their germination and the subsequent toxin production seem to be largely dependent. Antisepsis always tends to bring about a wound environment unfavorable for tetanus infection.

Immunization.—In addition to aseptic surgery and the adequate management of traumatisms, the use of tetanus antiserum is of the greatest value. This is especially indicated wherever the nature of

the wound and the local prevalence of tetanus cause the infection to be especially feared.

Wounds of the lower extremities and others especially exposed to contamination with soil or manure should always be regarded as a warrant for conferring passive immunity as a measure of safety. In tetanus territory, the serum injections are imperative in all cases of traumatism, and in such surgical procedures as castration, docking and others, their use is fully justified in the light of experience already available.

The antiserum has only an antitoxic action in that it combines with the circulating toxin and prevents it from satisfying its specific affinity for the neuron protoplasm. Once this has taken place, it cannot be undone; there is also evidence which tends to show that the antitoxin does not even enter the central nervous structures either by the blood or the lymph or by the axons. The antitoxin merely destroys the toxin in the circulation, and in this indirect manner safeguards the nerve centers. Hence it is quite imperative that serum injections should be made as soon as possible after the traumatism took place or after a surgical operation was completed.

Only massive doses of the antitoxin must be given, and as the immunity conferred in this manner persists for no longer than from two to six weeks, the repetition of the injection, once, twice, or even three times, at intervals of from ten to twelve days, is fully warranted.

Dried antitetanic serum has been recommended as a prophylactic dusting powder for wounds. It should not be depended on as a sole measure of protection, but used in conjunction with the serum injections it may increase the degree of safety.

The results of prophylactic serum injections have been most excellent; in certain tetanus territories they caused the normal tetanus morbidity of 30 per cent to be reduced to zero.

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CHAPTER XXVIII

HEMORRHAGIC SEPTICEMIA

HEMORRHAGIC septicemia, or pasteurellosis, is a collective name applied to certain animal diseases which have, as their primary cause, varieties, strains or types of a more or less narrowly defined bacterial species designated as *Bacillus bipolaris septicus* and which are characterized by a general blood infection leading to hemorrhagic inflammatory processes in various organs and parts.

In accordance with the animal species in which this infection is a primary cause of disturbances of a pathologic nature, the malady is variously designated. Game and cattle septicemia, barbone of buffaloes of southern Europe and the Orient, fowl cholera, reindeer septicemia, camel septicemia, elephant septicemia, similar diseases of sheep, rabbits and ferrets, as well as swine plague and pleuropneumonia of calves are commonly included in the group.

The disease in buffaloes (not to be confounded with the American bison) was the first one to be described more than a century ago and had been known for a long time even then. An early experimental attempt with a disease belonging to the hemorrhagic septicemia group was that of Coze and Feltz who transmitted a peracute infection to rabbits by means of putrid organic material.

Hueppe, in 1886, experimenting with cultures, obtained from cases of game septicemia, swine plague, rabbit septicemia and fowl cholera, was led to conclude by his results that these diseases were but forms of one and the same infection now designated as hemorrhagic septicemia.

Since Hueppe's day much has been written about hemorrhagic septicemia and its etiologic factor. The ubiquity of the latter and its tendency to find a habitat in any *locus minoris resistantiae* which the animal body may have to offer has led to much confusion in literature as well as in livestock sanitary practice.

The mere finding in certain lesions of bacteria showing the peculiar staining fashion of *B. bipolaris septicus* has often been accepted as prima facie evidence that they played a primary etiologic part. Necessarily, faulty conclusions were an inevitable result.

As von Hutyra but recently pointed out, simple catarrhal conditions and bronchial pneumonia have been confused with hemorrhagic septicemia and immunizing procedures applied only because a bipolar staining organism was found in the lesions. Not only were such practices without the slightest value, but in the presence of such a disease as hog-cholera, for instance, they gave rise to no small amount of confusion and materially obscured the problem presented by this, and othêr diseases.

In a similar manner has the presence of hemorrhages in parts and organs of the body been regarded, merely because they are not uncommon in this malady, as evidence of hemorrhagic septicemia, frequently without bacteriologic examination and sometimes even in the face of negative results of the latter. The mere presence of bipolar staining organisms and of multiple hemorrhages cannot always be accepted as evidence that they are the primary cause of disease in the animals involved.

That the *B. bipolaris septicus, per se,* is capable of causing serious and often highly fatal disease in livestock cannot, however, be doubted. The ravages among the buffaloes of the Orient, the frequent very disastrous outbreaks of fowl cholera, as well as occasional outbreaks of a true septicemia in cattle, sheep, game animals and other species are sufficient to show the capacity for mischief which may be associated with this organism.

In disease of which the *B. bipolaris septicus* is the primary etiologic factor, the intensity of the infection largely determines the course of the disease. This may be acute, subacute or chronic. In the first group belong the cases of overpowering septicemic disease rapidly followed by death.

When the infection is less intense, the disturbance may require several days to run its course, while edematous swellings of the subcutis, hemorrhages in various parts and inflammatory processes of the respiratory and intestinal tract may develop. In such cases, pneumonia is not uncommonly the direct cause of death, and lymph node involvement is commonly seen.

In the more benign forms of hemorrhagic septicemia a chronic course of the disease may be observed, and then there are apt to develop purulent or necrotic foci in which the causative organisms may be encountered in great numbers and in pure culture.

In the oriental buffalo disease and in fowl cholera the infection shows itself in its most malignant form, and similar cases have apparently also been observed in other animals. Birds affected with

fowl cholera commonly succumb to the infection within a remarkably short space of time.

In such cases lesions are often entirely absent while the blood stream is swarming with bacilli. In the subacute type of fowl cholera, the birds become somnolent and may linger for some days. After death such fowls may show an acute enteritis, pneumonia, and petechial hemorrhages in various parts, and the liver frequently presents small, yellowish, necrotic foci. Some of the cases terminate in a chronic malaise in which yellow, caseous, necrotic areas may be found in different parts of the body.

Parenchymatous damage may be observed in all forms of hemorrhagic septicemia and in all species of animals involved in the infection.

Hemorrhagic septicemia has been reported from many countries. In all parts of the far East it is more or less prevalent, especially among the buffaloes, in which an extraordinary malignant form of the disease is apt to occur. Fowl cholera outbreaks are common in most countries devoted to poultry husbandry.

Localized outbreaks in cattle, sheep and swine have been observed in several parts of the world, and local epizootics due to the *B. bipolar septicus* among young cattle and older calves have occurred as stable outbreaks.

In this country, fowl cholera is the form of hemorrhagic septicemia most frequently observed. Outbreaks among cattle and sheep also have been reported. On the whole, mammalian pasteurellosis is not a very common disease on this continent.

The outbreaks of hemorrhagic septicemia vary in behavior. Sometimes they are more or less isolated, whereas in the more virulent forms of the disease, such as barbone, neighboring territory may become seriously involved. In most outbreaks in cattle and sheep, only a few animals, probably not more than 10 per cent of a given herd become affected, and even in the more virulent fowl cholera, a large part of the birds in an infected flock may escape disaster.

Outbreaks among fowls in which a morbidity rate of from 90 to 100 per cent prevailed have been observed, but such occurrences are certainly not common in this country. On the other hand, the disease among waterfowl is more apt to be characterized by an extremely high rate of morbidity and mortality.

Isolated cases are not rare. One or two cases of avian hemorrhagic septicemia may suddenly appear in a given flock and perish without more birds becoming involved in the malady. Fox reports that, in

the zoological collection under his supervision, hemorrhagic septicemia appeared among mammals and birds only as single cases with the exception of those of two Barbary apes which had been in separate cages side by side.

The mortality among animals affected with the disease is usually high, commonly ranging between 50 and 100 per cent of the affected animals. The death-rate appears to be influenced by the species of animal involved as well as by the virulence of the invading microorganism.

Susceptible Species.—Many animal species have been found to harbor the *B. bipolaris septicus* not always in a manner to indicate susceptibility on the part of the former, or of specific pathogenicity on the part of the latter. The susceptibility to septicemic disease caused by the organism is often more individual than specific, and the development of actual disease appears on the one hand to be due to an exalted virulence of the bacilli and on the other to a state of reduced or impaired resistance of the animal in which they happen to find lodgment.

The introduction of avirulent organisms into animals subject to depressing influences may be followed by their dissemination throughout the body and by their acquiring a distinct pathogenicity. Their virulence may thus become so exalted that, even in animals normally resistant, exposure may result in septicemic disease. This may happen in several species, perhaps more readily in some than in others.

Susceptibility to hemorrhagic septicemia may be regarded as relative, and even the fact that only one species becomes involved in an outbreak cannot be accepted as evidence of inherent susceptibility.

It has been observed that outbreaks, as well as sporadic cases of septicemic disease primarily due to *B. bipolaris septicus*, are not rare in buffaloes, bisons, cattle, sheep, game animals and birds. Instances in which the infection was communicated from one species to another have been reported.

The highest degree of susceptibility is shown by rabbits, mice and guinea-pigs. In the spontaneous disease this degree of susceptibility is sometimes equaled by that shown by geese and ducks in certain outbreaks of fowl cholera.

Fox encountered hemorrhagic septicemia in carnivora, ungulata, rodents, primates and birds forming part of a zoological collection.

The Virus of Hemorrhagic Septicemia.—The *B. bipolaris septicus* is widely distributed in nature, often showing a tendency to cling to certain localities. In these the organism is more or less ubiquitous

and has been found in soil, water and foodstuffs. As facultative parasites they are apt to occur in the nasal cavities, pharynx, tonsils, bronchi and lungs of healthy animals belonging to many species.

The bacilli frequently play the part of secondary invaders, and in that capacity they are not infrequently encountered in lesions arising from other primary causes. The organisms have a marked tendency to invade any *locus minoris resistantiae* which happens to be present in the animal body.

In current nomenclature the organism is commonly named after the animal species in which it was associated with actual disease. At the most, such forms may be regarded as mere varieties, and can scarcely be accepted as distinct species. They cannot be differentiated by present bacteriologic methods, and although they may display a more or less distinct affinity for certain species involved in actual outbreaks, there can scarcely be any doubt that in their various relations as causes of septicemic disease they represent only one bacterial species.

In animals suffering from the classical form of the disorder under consideration, the bacilli are present in the blood stream, in various organs involved in the infection, in the naso-pharyngeal mucus, the saliva, the feces, the urine, and in cases of barbone they have also been found in the milk.

In the dry, caseous lesions of the more chronic forms of the malady, the bacteria also may be found in varying numbers and then not infrequently in company with other pathogens. In such localizations they may retain their viability and virulence for long periods. The bacillus responsible for fowl cholera fed to chickens was found to persist in the meat for 6 months.

It is by no means impossible that *B. bipolaris septicus* is able to exist as a saprophyte and to propagate itself in organic materials, polluted water, etc. On the whole, it is quite vulnerable to external influences. Hemorrhagic intestinal discharges kept at a temperature of 5° C. remained virulent for 18 days, but when stored at 15° C. the virulence had disappeared in 11 days.

A more marked resistance was shown toward the influences associated with putrefaction. In putrid material the bacilli remained alive for several weeks, even months. In manure they survive for at least 1 month, but in urine removed from animals dead with the disease, the bacteria persisted only for 5 to 9 days. Inoculated into garden earth the bacilli remained virulent for 3 months, but when kept in spring water the virulence had vanished in 2 to 3 weeks.

Infective peritoneal fluid dried on silk threads and exposed to daylight had become innocuous after 48 hours, but when it was kept in the dark the virulence was maintained for 24 hours longer. Bacilli contained in chicken liver, dried to a horny substance and kept at room temperature, was still virulent after 3 weeks, but this quality had disappeared after 4 weeks.

Blood, and the intestinal content dried in a shady place remained virulent for 6 to 10 days, but when it was exposed to sunlight the virulence had disappeared in 3 days. The hides of animals dead with the septicemic malady lost their virulence after a period of drying ranging from 23 to 25 days; in some of the cases the virulence had disappeared in 15 to 18 days.

Virulent blood dried on glass while in the dark was found to be capable of producing disease for 24 days; when it was mixed with garden soil the virulence persisted for 29 to 50 days. When the same material was exposed to light, but protected against complete desiccation, the virulence was maintained for 35 to 44 days. In cultures on solid media, protected against light and drying, *B. bipolaris septicus* is apt to survive for weeks and months.

The virus of hemorrhagic septicemia is quite sensitive to high temperatures although it resists freezing with impunity. Exposure for 1 hour to 45 to 50° C. kills the bacilli, but not with absolute constancy. On the other hand, an exposure to a heat of 55° C. destroys the virus after 45 minutes.

Contained in parts of carcasses the organisms are killed by a half-hour exposure to 45° to 46° C.; higher temperatures dispose of them in a few minutes.

B. bipolaris septicus shows but little resistance to chemical disinfectants. It succumbs rapidly in a 2 or 3 per cent solution of phenol. A 5 per cent solution kills the organism in 1 minute, a 3 per cent solution in 2 minutes and even a 0.5 per cent solution kills the bacilli in 15 minutes.

A 5 per cent limewater destroys the virus in 1 minute, and a 1 per cent solution does so in 4 to 5 minutes. Pieces of virulent hides kept in a 10 per cent suspension of lime in water were no longer virulent after 24 hours.

Calcium hypochlorite in a 0.1 per cent watery solution destroys the virus in 1 minute. A 3 per cent solution of sodium carbonate at a temperature of 50° C. destroys the bacilli in 3 minutes, and a 0.1 per cent solution of mercuric chloride brought about similar results in the same length of time.

Modes and Vehicles of Infection.—Animals in a state of susceptibility may become infected by the bacilli supplied by various sources. The organisms may be present in a given environment as mere saprophytes endowed with a more or less developed degree of pathogenicity. When they are introduced into the body of an animal, their virulence may increase and become further exalted by passage from host to host. In this manner a virulent septicemic malady may come about in which the bacilli are multiplied in a stupendous number and disseminate in the surroundings. Or the virus may occur in the form of comparatively harmless parasites in the body of healthy animals which eliminate them and thus contribute to the stock of organisms already present in the environment.

It is to be assumed that bacilli cast off by animals involved in the peracute and acute forms of hemorrhagic septicemia constitute the more dangerous infective agents; chronic carriers may also be a hazard, perhaps in a less conspicuous manner.

The hemorrhagic septicemia of game animals, cattle and buffaloes commonly shows itself in the areas involved as a typical soil-borne disease. Whether or not the soil infection is caused by bacteria leading a purely saprophytic existence or by those derived from infected animals is not definitely known. The latter source, of course, is always a manifest possibility.

The virus leaves the body of an infected animal in various secretions and excretions; the presence of carcasses dead with septicemic disease may also become a source of environmental contamination. The feces, urine, saliva, nasal secretions and pulmonary discharges of affected animals have frequently been found to be virulent, and the blood and carelessly disposed of viscera of sick animals or virus carriers may also serve as sources of infection.

The presence of carriers must always be reckoned with in all species and particularly in avian disease. In such fowls the etiologic microbes of cholera are commonly encountered in the nasal mucus, in necrotic foci in various parts of the body, in the exudates of chronically involved serosa and synovial membranes. They occur also in the caseous plugs found in the lungs, the intestines, the gall bladder and the oviduct. Birds so affected must be looked upon as formidable factors in the maintenance of infection in the flock concerned.

Webster and associates found that healthy pullets which had become carriers during a previous year served as infection reservoirs, and in general a relatively high carrier rate was paralleled by a high mortality rate.

Contaminated food and water are commonly accepted as important vehicles of infection. However, the possibility of direct-contact infection must certainly be admitted; evidence is not lacking that this is a common mode in the transmission of fowl cholera, if not the most important one. On the other hand, the direct transmission of hemorrhagic septicemia from animal to animal is denied by certain observers.

Many authors believe that flying, biting insects may transmit the disease, and Dammann and Oppermann succeeded in showing that such a transmission actually took place, *Simulia ornata* serving as the vector.

The digestive and respiratory tracts are looked upon as the more common ports of entry for the virus, which may also be introduced through wounds and abrasions of the skin and mucosae.

Attempts at artificial infection have not yielded uniform results. Most healthy animals resist infection introduced by the feeding of virulent material, although in one reported experiment, a bull fed with 1 gram of feces of a calf affected with septicemic disease died as a result 54 hours later.

On the whole, it seems difficult to induce hemorrhagic septicemia by introducing the virus into the digestive tract. The writer witnessed the feeding of hundreds of pounds of rabbit carcasses dead with *B. bipolaris septicus* infection derived from various avian and mammalian sources to a small number (4) of young swine, without the latter showing the slightest interference with their normal status of health.

Webster and associates, while experimenting with fowl cholera, failed to induce the disease by the feeding of virulent material, but when they introduced this material into the upper air passages, it caused typical cholera, even if more than half of the birds proved to be fully resistant.

Müller found that the feeding of highly virulent fowl cholera material was, with but few exceptions, well tolerated by fowls, although virulent bacilli appeared in their droppings within 24 hours. In some of his subjects the virus was no longer present after 30 hours; in others they persisted for four months. In a number of the birds, various organs still contained virulent bacilli after a lapse of six months.

Subcutaneous, intravenous or intraperitoneal inoculations are more or less dangerous for most animal species, although attempts to produce disease in this manner do not always produce positive,

acute infection. If the organisms are injected while at the height of their virulence, fatal infection may be induced, but it is by no means certain that this can be indefinitely repeated.

In other attempts of this nature the results may be entirely negative. On the whole, failure to induce a typical septicemic disease is not an uncommon experience even if inoculation may be followed by a general loss of flesh or localized joint involvement.

In repeated efforts to induce the disease in cattle by the inoculation of various bovine strains of *B. bipolaris septicus* the author succeeded only once. In that case the bacilli were mixed in the solution of a foreign protein against which the subjects were anaphylactically sensitized. The suspension was used as the intoxicating dose and one of the animals developed a localized pneumonia in which the organisms occurred in such a manner that the lesions could be charged to their account. It seems reasonable to assume that the resulting anaphylactic shock had removed or impaired all resistance to infection, but even in that case the infection failed to bring about a typical septicemia. His efforts to infect healthy swine by means of intravenous inoculation always resulted in failure. Similar results were reported by Schalk and Roderick, regardless of the adverse living conditions to which their subjects were previously exposed.

In actual outbreaks of septicemic disease the cases are most commonly confined to a single animal species. To this general rule there may, however, be certain exceptions. At least, it has been observed that the barbone among the buffaloes of southern Italy was apparently communicated to colts, calves and swine.

In experiments, a number of avian species were successfully infected with swine material. Such results are quite exceptional, but they tend to show that, before unreservedly accepting spontaneous, purely environmental infection as the source of septicemic disease among a given species, the possibility of some other species supplying the virus must be given consideration.

Hemorrhagic septicemia may be transported from place to place by means of affected or virus-carrying animals, wherever the malady constitutes a common menace. In this country, fowl cholera, at least, is commonly introduced into healthy flocks by newly purchased poultry or by birds returning from shows and exhibitions. The part played by flying birds as vehicles of infection must be admitted on empirical grounds.

When susceptibility on the part of the host animal combines with an exalted virulence on the part of the invading *B. bipolaris septicus,*

the latter is apt to multiply and to be rapidly disseminated throughout the body. Thus there may come about a virus onslaught of such intensity that death may follow within a space of 6 to 36 hours. This is not uncommonly the case in outbreaks of barbone and fowl cholera.

Factors Favoring Infection.—There is a consensus of opinion among authors that predisposing influences play a prominent part in the etiology of hemorrhagic septicemic diseases among the various types of livestock. The *modus operandi* of such factors is by no means thoroughly understood and is largely a subject of speculation and hypothesis. Apparently their action is dependent on the reciprocal functions of the influences associated with the environment, the actual status of susceptibility of the animals concerned and the pathogenicity of the virus.

The influence of environmental conditions on the resistance of animals to the infection is generally recognized. Especially mentioned are such factors as chilling, unhygienic stable conditions, undernourishment, the fatigue of long drives and the exposure to the adverse conditions incidental to long journeys by rail and ship. Sporadic cases of hemorrhagic septicemia as well as regular outbreaks have been observed after sudden changes of the weather and chilling, soaking rains.

The game and cattle septicemia of central Europe is apt to present itself as a typical soil-borne disease during the inclement meteorologic conditions of spring and autumn while the animals are in the open. Under similar circumstances the malady appears more rarely among stabled animals.

The reduced vitality of sheep in consequence of long-distance rail transportation is regarded to be a very important etiologic factor in the initiation of the disease, although it must be admitted that many shipments simultaneously exposed did not become affected by the disorder.

In one reported outbreak among sheep, a special predisposition was attributed to the fact that during the time required for cleaning of the stable the animals had to remain in the open during a cold rain. In India, the disease is prevalent among cattle and buffaloes during the rainy season and is then apparently associated with low and badly drained lands.

Not only is the susceptibility to infection apparently increased by the factors enumerated above, but the presence of other primary morbid conditions is also a potent one. Animals in an impaired state of health are less resistant than the more robust ones. In young

lambs, living under unfavorable stabling conditions and subject to digestive disturbances incidental to the weaning period, the liability to septicemic disease in the presence of the virus may be materially increased. A marked parasitism is likewise apt to reduce the resistance to infection.

That a highly developed pathogenicity of *B. bipolaris septicus* is a potent factor in the etiology of septicemic disease is obvious enough. This pathogenicity, however, is commonly an unstable one, and the influences under which it again disappears have thus far remained in the dark.

Bacilli of seemingly purely saprophytic antecedents, either avirulent or feebly virulent, under the operation of unknown factors assume and accumulate disease-producing qualities, and may then become capable of causing severe illness. It is commonly assumed that passage from animal to animal is instrumental in bringing this about, and experimental evidence supports this view. Such organisms may again return to their saprophytic status, may lose their virulence after leaving the animal body or even before they do so.

The host-parasite relations in *B. bipolaris* infection are summarized by Patton, who recognizes three distinct situations. One in which the host is either without susceptibility or possibly fortified by a degree of immunity sufficient to successfully dispose of the invading organisms. Or, the capacity to invade on the part of the microorganism and the power to resist invasion on the part of the host are more nearly in equilibrium. When this condition prevails, a localized infection or chronic disease may come about. In a third situation the host is entirely unable to defend itself against the parasite when acute septicemia disease is apt to declare itself.

Webster and associates traced the successive phases of an outbreak with reference to avian hemorrhagic septicemia. First, some influence operating in a given population tends to decrease the factor of resistance. The impairment of resistance causes a reciprocal rise in the number of carriers and in the volume of available virus. This increase in dosage is followed by the epizootic outbreaks without a demonstrable or significant exaltation of the virulence of the microbes.

Outbreaks not uncommonly come to a halt before a conspicuous number of exposed animals have become involved. Whether this phenomenon is based upon an absolute insusceptibility of the individuals which escape disease or upon an active immunity acquired by the exposure is difficult to determine.

Many authors have satisfied themselves that recovery from the

disease engenders an immunity, but in the face of certain experimental evidence revealing a lack of susceptibility, permanent or transitory, as the case may be, it will remain quite difficult to interpret this interesting epizootologic phenomenon correctly.

Prophylaxis.—Wherever hemorrhagic septicemia has to be reckoned with as a hazard to livestock, care should be exercised when new animals are to be introduced in a given herd or flock. Prudence demands that cattle or sheep which may have been exposed to the infection be kept in segregation for a time, particularly if they were subjected to influences which tend to reduce their natural resistance.

Similar steps are to be taken with reference to avian hemorrhagic septicemia, and fowls returning from shows should not be admitted to a disease-free flock until after a segregation of one or two weeks' duration. As a further precautionary measure it is sometimes advisable to keep a small number of fowls in contact with the isolated birds in order to test their possible infectivity.

Pastures and other enclosures where the disease has appeared before should be abandoned by the species concerned for one or more seasons. If the drainage of such areas is defective, attempts should be made to correct the fault. The filling or abandonment of ponds and pools frequented by waterfowls are potent factors in preventing fowl cholera among this type of poultry.

Infected sheep folds and stables should also be avoided for sheep, lambs especially, for a season, unless such enclosures lend themselves to a thorough disinfection or other means of environmental amelioration. In the face of an existing hemorrhagic septicemia hazard, it is preferable that lambs be weaned at pasture rather than during their occupancy of yards and other enclosures of restricted area.

Sanitary management, stable hygiene and a judicious feeding régime are of manifest prophylactic value for all types of livestock, especially because the exclusion of other pathogenic microbes and gross parasites removes an important predisposing cause of the malady.

In actual outbreaks, the healthy animals should at once be placed in enclosures other than the one in which the disease has declared itself. If it should be possible or practicable to divide the animals thus removed into small groups, this is to be recommended as an additional means of protection. In the case of barbone and other forms of bovine pasteurellosis, the prompt stabling of the healthy animals is of proved value.

In epizootics of fowl cholera, diseased or suspected fowls should

be killed and destroyed by burning. The premises involved should be carefully searched for dead fowls which are to be disposed of in a similar fashion.

The removal of all body wastes and stable litter, and the adequate disinfection of stables and enclosures, are essential prophylactic measures.

Immunization.—Since the classic studies on bacterial attenuation by Pasteur, half a century ago, numerous attempts have been made to secure a dependable, safe and practicable method to bring about an artificial immunity of sufficient potency to be useful in livestock sanitary practice wherever hemorrhagic septicemia is a more or less constant menace. In spite of these efforts, it does not appear that a satisfactory method of conferring immunity against *B. bipolaris septicus* has thus far become available.

As in Pasteur's initial attempts with his well-known fowl cholera vaccine, in many other trials the experiments were fascinating and quite often they promised well, but in the end they failed to establish methods constantly dependable in prophylaxis.

Pasteur's vaccine, composed of aged attenuated cultures, after some good results, proved to be of little or no value in combating fowl cholera, and a similar experience was gained with vaccines made with organisms subjected to a considerable variety of attenuating influences. Patton, discussing fowl cholera, aptly summarized the status of artificial immunization against that disease by saying: "Not unmindful that Pasteur's original experiments were carried out with this organism nor the apparent success of biological treatment in the hands of investigators, yet in the light of our present knowledge of the disease much information is to be revealed before commending any preventive measures beyond those of sanitation, isolation and quarantine."

Avirulent or attenuated cultures used to immunize against hemorrhagic septicemia in species other than fowls brought but variable results. In experiments as well as in field trials they have frequently inspired hope of a solution of the problem which they have subsequently failed to fulfill. In some instances, even, the safety of the use of such materials was questioned. Mieszner and Schern, commenting on the feeble protection afforded by the inoculations, state that in spite of the immunization the bacteria maintain their virulence for four months and are apt to create virus carriers.

Newson and Cross resorting to the use of live cultures when immunizing sheep were led to believe that by this means the animals

acquired some protection against lethal doses. In a later communication, however, one of these authors reported more or less disastrous results following the use of live cultures in sheep.

Killed cultures or bacterins have long been in vogue, and their use does not appear to be accompanied by danger. Their value as immunizing agents is probably quite negligible. Gallagher found that no noticeable resistance is conferred on fowls by the use of killed fowl cholera bacilli as immunizing agents, but in his hands live cultures of a selected strain conferred a marked resistance.

Van Es and Martin showed that the vaccines and bacterins of commerce, sold for the prevention of mammalian and avian hemorrhagic septicemia, were uniformly worthless. Graham and Schwarze reported that experimental animals treated with bacterins did not appear to be more tolerant to the infection than the ones not treated at all. To Newsom and Cross it appeared that the ovine strains of *B. Bipolaris septicus* used by them gave little protection, if any, to rabbits or sheep when the organisms were destroyed by heat and suggested further that the vaccine used by them rendered animals more susceptible to the organism. On the other hand, Manninger, Staub, Szasz, Pfeiler, Baldrey, Holmes and others report more or less favorably about their vaccination results in experiments as well as in the field.

Miller and associates, observing the results of bacterin treatment in animals passing through stockyards, found that the results in treated and untreated animals were about the same. They suggest, however, that if the injection had been made some days earlier the results might have been better. These observations lose much of their value because exposure to hemorrhagic septicemia was apparently taken for granted and not proved by any exact method.

The use of immune serum alone or in combination with virulent cultures in cattle and buffaloes found favor with Holmes, Leurink, and Blin and Carougeau, and Italian workers also claimed good results after three inoculations of 1 c.c. of the blood of pigeons dead with the disease. That serum injections are not an absolute means of protection was indicated by Mieszner and Schern, who reported the death of 68 animals of the 117 treated.

Beginning with Citron in 1906, immunization experiments with natural aggressins and bacterial extract have been repeatedly made. Some of these experiments were especially indicative of the possibility of engendering immunity by this method, and even in the few field observations the results were apparently favorable. The experi-

mental results reported by Gochenour in 1924 showed that his test animals actually became resistant.

Whether or not the present aggressin sold for immunization against hemorrhagic septicemia will fare better than the ones developed during an earlier period or than the many other immunizing agents in actual field experience cannot be foretold.

In the stock yard material collected by Miller and associates, the morbidity of aggressin-treated animals was slightly greater than in the ones not treated, but in the absence of data regarding specific exposure the value of such observations remains in doubt.

In few other diseases have so many methods of immunization been proposed or suggested as in the pasteurelloses. Monovalent and polyvalent vaccines and sera, virulent and avirulent cultures, bacterins, aggressins and bacterial extracts, special immunizing strains and bacilli which were deprived of their reproductive powers, often justified by honest, disinterested experiments, have been tried without thus far bringing forth a dependable method by which the septicemic disease caused by *B. bipolaris septicus* can be adequately controlled or prevented. Good results are reported frequently enough, sometimes with apparent justification and sometimes obtained in places and herds where the disease was not proved to exist. Some of these reports may even have been solely based on commercial inspiration.

Much confusion has thus been created, largely arising from the fact that some very specific difficulties are probably most firmly attached to the problem. Among these the instability of the pathogenic and antigenic values of *B. bipolaris septicus* and the uncertainty of host susceptibility are probably the more important ones.

There is no certainty that in either of these qualities the organisms used in the experiments will remain the same for any length of time. A culture of extreme virulence or of apparent antigenic value may have lost these qualities within a relatively brief period.

In some of the experiments of Van Es and Martin it could be shown that animals treated with immune serum and a virulent culture did not become actively immune or, in other words, that the virus injected into a passively immune animal failed to render this immunity at all durable. Animals so treated uniformly succumbed to a subsequent virus injection, identical to the one first administered.

Patton suggests that different strains of the same organism will vary considerably in their ability to produce antibodies, others may sensitize rather than immunize.

Even in actual practice it is often extremely difficult to form a

correct estimate of the value of alleged immunizing procedures. Von Hutyra, in a recent publication, urges caution in drawing conclusions from field experience and states that because an outbreak of hemorrhagic septicemia is always apt to terminate of its own accord good results are frequently merely simulated, and for this reason alone prudence is indicated in the evaluation of so-called immunizing substances.

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CHAPTER XXIX

PIG TYPHUS

THE investigations of the diseases of swine carried on after the pioneer work of Salmon and Smith showed that hog-cholera, as studied by them, was a complex of at least two morbid entities. They had discovered the etiologic factor of one and had named it the bacillus of hog-cholera. It was not until many years later that it was found that the highly contagious disease which is still designated hog-cholera has an entirely different cause.

The disease of which Salmon and Smith had discovered the cause is the one which is now known as pig typhus, paratyphus suis, necrotic enteritis, infectious caseous enteritis or even as bacillary hog-cholera.

It is a disorder caused by bacteria of the colon-typhoid group and principally characterized by enteritis, intestinal ulcerations, pulmonary complications and not infrequently by a high degree of emaciation and cachexia. The disease is usually chronic in its course. It may last several weeks or even months before it terminates in either death or recovery. Even the latter issue is not always an advantage, for many pigs, after apparent recovery, fail to thrive and grow, and remain unprofitable.

Pig typhus shows no tendency to disseminate itself over large areas, but is more inclined to remain confined to certain herds or establishments.

The disorder is peculiar to young pigs and in many parts of the hog-producing sections of North America it is probably the most profuse source of losses among this class of swine. Paratyphus infection is occasionally encountered in older swine, but as a general rule a pig which has reached the age of four months will no longer become affected.

The mortality varies as well as the morbidity in a given herd. A loss of 78 per cent has been observed in artificially infected pigs, and a death-rate of from 25 to 60 per cent is by no means rare among naturally infected animals. In establishments where the farrowing

season is unduly prolonged the losses are apt to be heavy, if an unsuitable environment combines with a growing virulence of the causative organisms to make the disease a very formidable one.

The Virus of Pig Typhus.—There is evidence that shows that the clinical and pathologic anatomic phenomena to which the collective name of pig typhus can be given may be caused by a number of supposedly specifically distinct microbic species. The latter, however, are all colon-typhoid intermediates commonly designated as belonging to the paratyphus group. As the etiologic factors of pig typhus, the *B. suipestifer* (Salmon and Smith), the *B. paratyphi suis* (Glässer) and the *B. enteritidis* (Gärtner) are especially named. It is quite probable that in the United States, as well as in the various swine-growing regions of Europe, the disease can be most commonly attributed to varieties or strains of *B. suipestifer.*

It is by no means impossible that other microbic forms which have from time to time been associated with pig typhus are so closely related to the organism mentioned that the finer distinctions made on bacteriologic or serologic grounds are of a rather minor importance when ways and means of prevention are to be devised.

The *B. suipestifer* occurs as an inhabitant of the intestinal tract of normal swine; in a series of 600 animals it could be isolated from 8.4 per cent. In older swine, especially, the microbe exists as a harmless parasite. Under certain conditions the organism may assume pathogenic characters for younger animals, and by passage from pig to pig in ever-increasing numbers this virulence may be materially exalted.

In affected animals the organisms can be found in the swollen or caseated mesenteric lymph nodes, or in the actually inflamed or cheesy foci of the intestines or the lungs. In the more acute, severe cases they may also be recovered from the spleen and the heart blood. The *B. necrophorus* is commonly present in the intestinal lesions as a secondary invader. The virus leaves the body of its host with the feces and is thus apt to contaminate soil, drinking water and food.

The organism is quite resistant to drying and in that condition may retain its viability and virulence for months. In water and in moist media the bacillus succumbs more rapidly as a result of saprophytic influences, the ambient temperature being a potent factor in determining the length of time required for its destruction. The latter is hastened by the alternation of drying and moisture, and to the influence of solar radiation the bacteria are likewise quite susceptible when not protected by a surrounding medium. The organ-

ism is readily destroyed by heat, 1 hour at 55° C. being sufficient for this purpose.

B. suipestifer is easily destroyed by most chemical disinfectants. A solution containing 1 per cent phenol or a saponified cresol kills it in 10 minutes, and a sublimate solution of 0.01 per cent has the same effect. A 1 per cent solution of copper sulphate destroys the germs in 3 minutes. A 2 per cent solution of iron sulphate kills it in 3 hours, and a 0.1 per cent solution of formalin brings about the same results in half that space of time.

Host Species.—Organisms belonging to the paratyphus group and other related colon-typhoid intermediates have been shown to be causative factors in intestinal disease and meat-poisoning in a number of animal species, including man. It is, therefore, by no means improbable that the microbic species which have an etiologic relation to pig typhus may be found to inhabit the intestinal canal of other animals just as they are known to be frequent parasites of healthy swine.

The host relations of these bacteria may thus be multiple, although their more pronounced pathogenic characters, so far as the domestic animals are concerned, are practically limited to young swine. In these animals the virus gives rise to a clinical and patho-anatomic state which is not found in the others.

From a viewpoint of livestock sanitarians it may thus be stated that the pig is the host species par excellence of the bacteria which are apt to cause the disease under consideration and the only one in which the infection leads to typical pathognomonic manifestations.

Under experimental conditions the *B. suipestifer* is pathogenic to mice, rats, rabbits and cavias; at least, these animals succumb with a varying degree of readiness to subcutaneous intravenous or alimentary infection. Its virulence for other animals, like adult swine, calves, monkeys, dogs and cats, is inconstant. Pigeons show but slight susceptibility, and fowls none at all.

Modes and Vehicles of Infection.—The bacilli responsible for pig typhus are eliminated with the feces of animals sick with the disease or of the older swine which serve as healthy virus carriers. The soil of hog yards as well as the litter of stables may thus become more or less permanently contaminated; this pollution can be readily extended to the food and drinking water, which then serve as the principal vehicles by which the virus is transferred to new hosts.

When infection takes place in the natural manner, the virus is taken in *per os,* and the bacilli are capable of directly infecting the

mucosa of mouth and pharynx as well as the tonsils without the intestinal mucosa being a previous seat of characteristic lesions. The introduction of the virus may also take place via the respiratory tract and may then give rise to a suipestifer bronchitis or a primary suipestifer pneumonia.

The length of the incubation period is variable, and the first symptoms may not be manifested for several days or even weeks. It is apparent that the amount of virus taken in is the principal factor which determines the length of the incubative stage.

Infection by indirect contact plays an important part. The animals first infected eliminate, with their evacuations, bacilli in such numbers as to cause positive infection in the hitherto more resistant members of a herd of pigs.

Factors Favoring Infection.—The occurrence of pig typhus in a herd of swine is in a large measure dependent on the presence of certain factors among which that of age is probably the most conspicuous. It is, above all, a disease peculiar to the young swine; animals over four months old, as a rule, are quite resistant to the infection.

Although older swine do not always prove themselves to be exempt, it is a matter of common observation that, even in herds severely ravaged by the disease, the more mature animals escape disaster. When older animals show the characteristic lesions they can be ascribed either to disease sustained during the juvenile period or to the exaltation of the virulence of bacilli normally present under the effect of a simultaneous infection by the filterable virus of hog-cholera. If such animals do not succumb to the latter, they may become formidable virus carriers, and they may play a very positive part in the maintenance of a pig typhus enzootic on certain farms.

In addition to the age factor there are other conditions which tend to favor the development of the disease. Adverse living conditions, such as inadequate or faulty feeding, a damp, cold or filthy environment, as well as sudden changes in the feeding régime, subsequent to weaning, must be reckoned among influences which bring about a certain degree of predisposition.

The hardships met by pigs farrowed too early when cold weather, lack of direct sunshine and the green feed combine to reduce body vigor and resistance to microbic invasion may account for a certain proportion of pig typhoid outbreaks.

Positive infection is to a large extent conditioned on the volume of virus which the animals are apt to take in. Hence the disease

is most common where young pigs are concentrated in a limited space, where fecal matter is apt to constitute a conspicuous ingredient of the upper soil layers, and where through their feeding habits the ingestion of large numbers of bacilli is a daily possibility. In such an environment the danger of infection is multipled by the drinking of surface water and the unavoidable pollution of the food with fecal matter.

Increase in virulence as the organisms pass from pig to pig must also be credited with an influence which tends to make for an increase in morbidity for a given herd.

In another chapter, attention was called to the fact that the susceptibility to suipestifer infection is increased by the simultaneous presence of the virus of hog-cholera and the exercise of the latter's pathogenicity.

Prophylaxis.—Pig typhus is a disease more particularly attached to certain farms and breeding establishments. As such, it occurs as small enzootics and has but little tendency to spread through a considerable portion of a swine population. This peculiarity largely arises from the fact that certain contributory factors play a conspicuous part in the causation of the disease.

The influence of these contributory or predisposing factors is probably not less than that of the more or less ubiquitous primary etiologic agent. It varies with the environment and with the manner of herd management, and hence the prophylaxis of pig typhus is, on the whole, a matter of private initiative and effort which, nevertheless, requires that certain general measures must be given consideration.

Elimination of Sources of Primary Infection.—With a considerable number of normal swine serving as hosts to the *B. suipestifer* and related microbic species, the elimination of primary infection sources would be a difficult, if not an impossible, undertaking. It should be remembered, however, that without certain contributory factors the danger arising from such normal infection carriers is usually not a conspicuous one. The number of bacilli eliminated by the carriers is relatively small and their virulence is low.

When, by the influence of adverse living conditions and an impaired power of resistance, pigs contract the disease, they, as sources of infection, become formidable agents of mischief. They eliminate large numbers of the causative microbes, the virulence of which is increased as they pass from animal to animal. It is obvious, thus, that such pigs should at least be segregated, and if they fail to show

evidence of recovery they should be destroyed. It is needless to say that exposed pigs not yet showing symptoms of the disease should be removed to uncontaminated yards or quarters, where the more harmful, contributory influences can be avoided.

Care should be taken that the body wastes of infected pigs cannot pollute the water or food supply of healthy stock, and yards in which the disease has developed should be abandoned for a period long enough for the completion of the process of biologic purification mentioned in another chapter (soil).

Stables, hog houses and other enclosures the construction of which renders disinfection possible, should be subjected to this process. The water supply and the feed offered to the healthy part of the herd should be selected with a view to exclude all possibility of contamination. Adequate disposal of carcasses dead with the disease must not be overlooked among the general measures which tend to do away with primary infection sources.

Elimination of Contributory Etiologic Factors.—The prevention of pig typhus is more dependent on the elimination of adverse contributory influences than on the destruction of the virus itself. These influences are connected with the animals to be protected as well as with the environment in which they live.

Pigs should be maintained in a good state of nutrition, and they should be protected against dampness and the inclemencies of the weather. Exposure to direct solar radiation and a ready access to green feed are most important factors in the maintenance of body vigor and the promotion of normal growth.

It is probable that the hardships and the lack of sunshine and green feed experienced by pigs born very early in a large measure cancels whatever advantage may be associated with the prevalent practice of early farrowing. The predisposition to certain juvenile diseases shown by such pigs is a plea for later births, and among these diseases pig typhus occupies a prominent position.

Another advantage associated with later arrival of pigs is the opportunity of bringing them to pasture quite early in life. There, green feed and out-of-door exposure to sunshine are available, and above all, at pasture there is less chance of the animals coming in intimate contact with heavily contaminated soil. At the same time, the wider range prevents a concentration of the microbic elements present in the feces of the older swine.

Under all circumstances, old hog lots, more or less continuously occupied by swine, old and young, should not be used for pigs less

than four months old. Pig typhus is the common penalty for exposing the animals to the fecal ingredients of such enclosures and to the pathogenic microbes apt to be present there.

Clean farrowing stalls, removal of the filth which clings to the surface of the brood sow's body and an early access to green pasture provided with adequate shelter are among the most potent measures in the prophylaxis of pig typhus.

Immunization.—On farms where pig typhus is a perennial problem and where an adverse environment or unfavorable living conditions cannot be avoided, immunization of the pigs soon after farrowing may be attempted as an experiment. Care should then be taken to prepare the vaccine or bacterin to be used from *B. suipestifer* or *B. paratyphus* strains, particularly associated with the enzootic under consideration.

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CHAPTER XXX

BACILLARY WHITE DIARRHEA

Bacillary white diarrhea is an acute septicemic disorder particularly fatal to young chicks. It is also encountered in adult fowls, in which it tends to assume a more chronic character with a localization of the infection in the ovary.

At this time, bacillary white diarrhea has become a definite problem wherever poultry husbandry is extensively practiced. The wide distribution of the infection has kept pace with the development of commercial hatcheries and the practice of custom hatching and trading in one-day-old chicks. Since the beginning of the present century, bacillary white diarrhea has steadily increased in economic importance. Not only is this phenomenon associated with the general prevalence of the disease, but in individual outbreaks also the losses may be very severe.

The malady impairs the fertility of eggs and it figures prominently as a cause of death of chicks in the course of incubation. Aside from the losses by death, bacillary white diarrhea is responsible for stunted and feeble chicks; in adult fowls the disorder not infrequently has to be reckoned with as a cause of impaired health and deaths.

Especially in chicks less than two weeks old are the death losses apt to be extremely severe. In infected lots of chicks the mortality rate ranges between 10 and 100 per cent of the effectives, and in certain districts not less than half of the chicks produced during a season may succumb to the disease.

As a rule, the disease asserts itself immediately after the chicks leave the shell. The affected chicks are dull, sleepy, droop their wings, show lack of appetite and often evidence of asphyxia.

Diarrhea is a common feature of the malady. The intestinal discharge is more apt to be slight than profuse. It is pasty, frothy, and in color ranges from a white to a light brownish tint. In outbreaks of more than usual virulence diarrhea may be entirely absent, the chicks dying before an intestinal disturbance had time to develop.

More commonly, there is a slight discharge which dries on the down around the vent and there gives rise to what poultrymen designate as "pasting up behind." Affected chicks habitually peep and chirp as if in constant pain.

In adult fowls the disease usually takes on a more chronic aspect. Many affected birds fail to show any evidence of illness during life; others manifest its presence by pallor of comb and visible mucosae, by loss of appetite and diarrhea. In many such birds the symptoms do not differ materially from those seen in fowl typhus.

The post-mortem inspection of chicks dead with the disease reveals emaciation and paleness of the viscera; the digestive tract is commonly empty or partially filled with a sticky, stringy fluid. The liver is degenerated, pale or yellowish in color, friable and marked by reddish streaks or patches. In about half of the cases the yolk is not absorbed. A fibrinous pericarditis is of common occurrence, and white nodular areas may be observed in the myocardium as well as in the lungs.

In the affected, adult fowls, the ovary is most frequently involved, and this is often accompanied by inflammatory changes of the serosa and general sepsis as the immediate cause of death.

Susceptible Species.—The disease has been encountered in turkeys and possibly also in ducks as isolated cases, but the common fowl is apparently the optimum host of the causative micro-organism. Cavias, rabbits, mice and pigeons have succumbed to artificial inoculations but it is doubtful that there exists a marked susceptibility on the part of these animals. Olney's observation of an outbreak of bacillary white diarrhea infection among a stock of rabbits which had been fed with non-fertile, incubator eggs, however, indicates that a mammalian species can acquire the disease by something like a natural contact. Cases in man arising from the consumption of infected eggs have thus far not been observed.

The Virus of Bacillary White Diarrhea.—The etiologic factor of bacillary white diarrhea is a colon-typhoid intermediate known as *Bacillus pullorum,* more recently also designated as *Salmonella pullorum.* The organism is closely related to *B. gallinarum.* Certain continental authors regard both organisms as two forms or strains of only one microbic species.

B. pullorum is to be found in the liver, spleen, heart blood and yolk sacks of chicks, as well as in the ovaries of adult carrier birds. Eggs produced by the latter contain the bacillus in proportions ranging from 2.5 to 95 per cent of the total number examined. The or-

ganism is present in the feces of affected chicks and probably occasionally also in that of infected adults.

The resistance of *B. pullorum* to external influences is not thoroughly known. There is ground for the belief that its vulnerability to various adverse factors resembles that of the fowl typhus microbe.

It shows but slight resistance to chemical disinfectants. Contained in bouillon cultures it was killed in 2 hours by a solution of mercuric chloride (1–60,000), by a phenol solution (1–220) and by a formalin solution (1–700). It is quite vulnerable to mineral acids and also to lactic acid. The latter added to a broth culture in the proportion of 1–400 killed the bacillus within 2 hours.

The organism is destroyed by boiling for 1 minute, but an exposure to 60° C. for 30 minutes was not sufficient to kill it.

The longevity of *B. pullorum* in soil or other parts of an environment has not been definitely determined. One observation showed evidence that the infection did not survive over winter in a brooder previously occupied by infected chicks.

Modes and Vehicles of Infection.—The extreme susceptibility to bacillary white diarrhea shown by very young chicks and the high mortality rate peculiar to them, as well as the more marked resistance to the infection combined with a more benign course of the disorder in adults, must be regarded as its most dominant features so far as its natural history is concerned. The part played by the infected adult fowl supplies the bacillary white diarrhea hazard to be encountered by the young of the succeeding generations.

Bacillary white diarrhea has attracted most attention and inflicted the greater part of the economic losses in connection with young chicks. But, however great its mortality rate may be in this age group, not all the infected chicks succumb to the disease. Those which become infected a few days after hatching show a greater resistance to the malady, and among such late infected chicks, probably among the younger ones as well, apparent recoveries are by no means uncommon. In such chicks the infection does not assume an overpowering septicemic form; it becomes localized; the birds concerned reach maturity and become virus carriers. In one instance, at least, it was shown that approximately half of the chicks which survived in an outbreak became carriers.

Such carrier birds commonly are in an apparently good state of health, even if adult fowls occasionally succumb to an acute exacerbation of the infection or to complications arising from secondary factors.

In the virus-carrying fowl, the ovary is the site of predilection for the causative microbes, which, in addition, have been encountered in the spleen, liver, heart and pericardium as well. The infected ovary, often functionally active, is of the greatest importance because of the fact that the eggs, in varying proportion, also contain the *B. pullorum* and in spite of this may become fertilized and eventually used for hatching purposes. Carrier birds have even been shown to be profitable as egg producers up to a certain age.

In the infected egg the chick readily becomes invaded and either dies within the shell or develops as an infected chick. The eggs from infection-carrying fowls have in this manner become the most common and the most prolific source of chick disease.

The infected egg, though of dominant importance in the etiology of the disease, is, however, not the only vehicle at the disposal of the virus. Chicks hatched from non-infected eggs but brought in contact with chicks suffering from bacillary white diarrhea may also acquire the infection. Food and water contaminated by the droppings of the diseased chicks as well as direct contact with the latter are responsible for the transmission. Infected soil or brooders may also play a part. The disease has been shown to be transmitted by means of artificially infected down or that of diseased chicks in forced draft incubators. Other infection hazards are associated with the practice of feeding infertile eggs in the raw state or with contacts with adult carrier birds.

The younger the chicks, the greater the susceptibility. There are indications that the susceptibility becomes greatly reduced after the age of two weeks has been reached, although the fact that fowls up to one year of age have become infected by the feeding of large amounts of broth cultures of *B. pullorum* may not be without practical significance.

The infection of adult fowls seems to be of uncommon occurrence so far as can be adduced from experimental evidence. The latter is, however, somewhat contradictory on this point, and observations made in the field furnish some indications that transmission of the infection among mature hens may actually take place. There is no concrete evidence that shows that the male bird plays a part in transmission.

Owing to the possibility of transmission by infected eggs, the practice of artificial incubation, commercial or custom hatching, has become greatly responsible for the wide dissemination of the disease during the last two or three decades. The acquisition of infected eggs, the transmission of the disease in incubators and brooders and the trade in infected day-old chicks have contributed to make bacillary

white diarrhea the greatest source of losses among poultry so far as numbers are concerned.

The phenomenon of bacillary white diarrhea, like that of so many other pathologic processes, tends to show to what extent the methods and technique of domestication are apt to influence morbidity.

Factors Favoring Infection.—All conditions which cause food and water to become contaminated by infected droppings, by remnants of infected eggs or incubator waste and which concentrate large numbers of chicks in incubators or brooders tend to favor the spread of bacillary white diarrhea and to increase its morbidity rate among recently hatched chicks.

The part played by such environmental factors, however, cannot be compared to the one exercised by age; the great susceptibility of young chicks more than any other influence is accountable for the marked prevalence of bacillary white diarrhea.

This susceptibility is greatest within the first 48 hours after hatching, although chicks 4 or 5 days old and even more are still liable to become acutely and fatally infected. On the other hand, acute cases are but rarely observed in chicks more than 1 month of age.

Prophylaxis.—The rejection of chicks which survived in an outbreak of bacillary white diarrhea as future breeding stock is, no doubt, the most essential of all prophylactic measures. Unexposed chicks set aside as reproducers must be kept separate from those which have been at any time in contact with the infection.

If such measures had been adopted soon after the natural history of the disease was revealed, the annoying problem presented by it today could most certainly have been avoided, and even now the practice would supply the most radical and least costly of all attempts at prevention.

In spite of the enormous prevalence of the malady, disease-free flocks can still be found; these should be chosen to furnish the breeding stock, and the eggs of all infected or exposed birds should not find their way to incubators or hatcheries.

At the present time, the prophylaxis of bacillary white diarrhea is almost entirely based upon the elimination of the carrier fowls as breeders, and this is possible of consummation by the systematic application of the agglutination test. There can be no doubt that, in spite of some of its defects, the testing of fowls has resulted in a reduction in chick morbidity in many flocks.

The principal disadvantage associated with this method of prophylaxis is the time required to free a flock completely of its infection

carriers. Several tests are necessary to accomplish this because infected birds are not always certain to constantly show a positive agglutination titer of the blood. A certain percentage of infected fowls react intermittently and even during periods of negative reactions may continue to produce eggs containing the bacilli.

This disadvantage may be somewhat overcome, however, by applying two or more tests instead of the annual one now commonly recommended. Such a practice would increase the cost of the procedure, but if this is of minor importance, fowls could be tested and culled sometime during autumn and the process repeated shortly before the eggs to be used for hatching purposes are produced.

Notwithstanding the imperfections encountered in testing practice, the weight of evidence is in its favor. There can scarcely be any doubt that chicks hatched from eggs produced in carefully tested and culled flocks show a much lower bacillary white diarrhea morbidity than those derived from flocks in which the freedom from disease was not challenged in the manner indicated.

The most notable measure of success in the control of the disorder under consideration is secured in flocks in which year after year all fowls are tested at least once annually and from which all reactors, even the doubtful ones, are promptly and completely eliminated.

The practice of eliminating the reacting birds must be supported by sanitary flock management, and public hatcheries should only use eggs from tested and culled flocks maintained under sanitary supervision. At this time no other practice is entirely safe.

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CHAPTER XXXI

FOWL TYPHUS

Fowl typhus is a specific, communicable disease of the common fowl, septicemic in character and marked by a more or less acute course. The malady was not recognized as a distinct entity among avian disorders until the development of bacteriology made this possible. It was identified first by Klein in England (1888) and some years later by Moore in this country.

Before that time, fowl typhus was commonly confused with fowl cholera. Its behavior, however, differs from the latter by its less acute character and by a slower progress of the infection in a given flock.

The disease has been described from many countries, and at the present time it is apt to be encountered wherever poultry husbandry is practiced to any extent. Fowls affected with typhus show drowsiness and dullness; diarrhea is frequently a marked feature. There is muscular atony and wings droop as a result. The feathers are ruffled, and comb and wattles may be abnormally pale.

Among the after-death changes the pallor of the musculature is often conspicuous. The blood is thin, watery, and when microscopically examined, it shows leucocytosis in a large proportion of the cases. As a rule, the spleen is enlarged and dark in color. The liver also is increased in volume. Its color may range from a light yellow to a dark bronze, the latter being more or less pathognomonic of the disorder. The liver substance is friable, and below its capsule, small, light-colored, necrotic areas may be noted.

The heart also may be found to be enlarged, and not infrequently the myocardium shows white nodular masses. Inflammatory changes of the serosa are encountered, and ovarian involvement is by no means rare. The kidneys are commonly swollen, and intestinal catarrh is practically always in evidence.

The disease usually runs its course in from 1 to 6 days and although manifestly diseased birds rarely recover, non-fatal infections, no doubt, do occur. The progress of the disease in an infected flock may be relatively slow, but in the end the losses by death may be quite severe. The mortality rate has been variously estimated owing to the fluctuations in virulence as well as to a certain inconstancy in trans-

mission opportunities. In some flocks only a single fowl may be taken by the disease, whereas in others, 90 to 100 per cent of the effectives may perish. Commonly an outbreak drags along for several weeks with a mortality of from 1 to 4 birds per day until at the end of two or three months a death toll of 75 to 85 per cent may have been exacted.

Susceptible Species.—Fowl typhus, though most common in fowls, has occasionally been observed also in turkeys, peafowls, guineafowls, pheasants, pigeons, cage birds and sparrows. It is even more uncommon in waterfowl, although its occurrence in ducks has been reported. The instability of the virulence of the causative micro-organism is probably responsible for certain contradictory statements regarding the susceptibility of rabbits, cavias and mice. Even in fowls, artificial infection is not always followed by positive results.

The Virus of Fowl Typhus.—The cause of fowl typhus, the *Bacillus gallinarum* of Klein, also described as *B. sanguinarium, B. typhi gallinarum alcalifaciens* and *B. paradysenteriae gallinarum,* is an organism belonging to the colon-typhoid group. It is closely related to *B. pullorum* and, by certain authors, is held to be identical to it.

The fowl typhus bacillus grows well in artificial media and can readily be isolated from the heart blood, spleen, liver, kidneys, myocardial nodules, lungs and bone marrow of affected fowls. In the chronic infection carriers, the ovary often appears to be a favorite site of the organism. Under artificial cultivation the virulence of the bacillus is apt to become rapidly impaired.

The organism is sensitive to moist heat and is killed within 10 minutes when exposed to a temperature of 62.5° C. It is more resistant to dry heat and was found to be still viable after a 5-minute exposure to 75° C. When the exposure was prolonged to 10 minutes the bacillus was killed. Dried on glass plates and kept in the dark the virus survived for about 3 months.

Direct sunlight is quite destructive to it, and even in a dried state it failed to resist an exposure for 30 hours. Contained in water and stored in the dark the organism remained alive for about 3 weeks, but when in a similar situation it was exposed to solar radiation it succumbed within 24 hours.

Field observations indicate that the fowl typhus bacillus survives in the soil for prolonged periods, but it is not always certain whether it did so in the soil or in the body or some carrier bird.

B. gallinarum is readily killed by disinfectants, and even weak solutions of phenol (0.1 per cent) or mercuric chloride (0.005 per cent) destroy the germs quite speedily.

Modes and Vehicles of Infection.—The disease can be transmitted by the feeding of infected food and by the usual methods of inoculation, but there is no constancy in the results obtained. Apparently either the fowls used in infection experiments show marked variations in susceptibility or the virulence of the etiologic factor is unstable or readily influenced by conditions as yet unknown.

The intestinal contents of the affected birds is nearly always infective, and hence the feces must be looked upon as the primary vehicle by which the virus is eliminated from the body. In the further transmission of the infection the part played by the soil is a prominent one, especially because in it the virus may remain active for some time. The soil serves as a reservoir for the virus, and by it the water taken in by the birds readily becomes contaminated. Hence the accumulations of surface water and open drains, as well as food picked up from the ground, must be regarded as very active vehicles of the infection.

The part played by apparently healthy infection carriers and spreaders must always be reckoned with in flocks in which typhus has occurred. It was definitely ascertained that fowls which were not fatally infected were still able to transmit the malady after a lapse of more than 2 months. After natural exposure, the incubation period, as a rule, extends from 4 to 6 days, but observations tend to show that this period may be prolonged to as much as 2 weeks.

There is evidence to show that fowl typhus may be transmitted by the egg, and that chicks hatched from such eggs develop a disease which can be distinguished from white bacillary diarrhea only by bacteriologic methods. Such a mode of transmission is not a usual one even if it may play a part oftener than is now suspected.

Factors Favoring Infection.—Of all the factors which may favor the development of fowl typhus outbreaks, none is more potent than an insalubrious environment. Access to surface water, soil occupied by generations of birds and grossly befouled by their droppings, are influences which overshadow all others. This probably explains why typhus is so common in the ordinary farm flocks which roam at large and where a sanitary supervision of the water and food supply cannot be exercised. In commercial flocks where more attention is paid to the details of sanitation the disease is relatively rare.

Wet seasons favor the propagation of the disease, and in certain areas there is a marked parallelism between precipitation and the incidence of fowl typhus. There can scarcely be any doubt that the phenomenon is associated with the rain water which is apt to be retained on the surface.

On the whole, the disease is more common during the spring and

early summer, which also may be due to the same cause inasmuch as the rate of evaporation is greater during a more advanced warm season. However, no part of the year is entirely exempt from outbreaks of the disorder.

Although several authors report that the disease particularly affects vigorous, mature birds, there is no great certainty that age is much of a factor in susceptibility. Disastrous outbreaks among the younger birds are by no means uncommon. It is not impossible that in order to interpret correctly the influence of age those exercised by season, rainfall and permeability of the soil must also enter into the consideration.

Fowls originating in areas where fowl typhus is of common occurrence have shown a greater resistance to the infection than birds taken from flocks in which the disorder had never been observed.

Prophylaxis.—Environmental hygiene and a scrupulous care exercised when new stock is to be introduced into a flock constitute the most dependable means of prophylaxis. The rotation of poultry yards and the elimination of questionable sources of drinking water can scarcely be dispensed with in areas where fowl typhus exists in a more or less enzootic form.

In actual outbreaks, the visibly affected birds should be destroyed and the healthy stock removed to clean ground. If there the flock can be divided in several small groups, doing so may have a certain value in dealing with the situation.

The virus carriers could be eliminated by means of appropriate serologic tests, but inasmuch as the number of reacting fowls in an infected flock may prove to be excessively large, it is doubtful if flock owners would readily submit to the additional cost. They may probably prefer to market the entire flock for slaughter purposes, a measure, radical as it is, not without merit under certain conditions.

The filth of infected yards should be carefully gathered and destroyed by fire, and after the ground has been plowed, the enclosure should remain unpopulated by fowls for a period of 9 to 12 months.

Eggs from infected flocks should not be used for hatching purposes and when the disease occurs in the younger brooder chicks, the measures directed against bacillary white diarrhea should find application.

Many authors make mention of favorable results obtained in experiments with immunologic methods. Highly potent immune sera were found to afford protection enduring for 2 to 3 weeks.

More lasting results were observed after the use of vaccine composed of killed or attenuated cultures of *B. gallinarum* or of avirulent

bacilli. Thus far, vaccination does not appear to have been applied on a scale sufficiently extensive to permit an unqualified recommendation of its adoption as a routine practice. Even if there were warrant for doing so, hygienic measures could not be dispensed with. The latter have thus far remained the most promising means of prophylaxis.

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CHAPTER XXXII

WHITE SCOURS

WHITE scours, or dysenteria neonatorum, is an acute, communicable disease of the new-born which, though primarily involving the intestine, is always inclined to assume a septicemic character. The disorder must have been observed from early times, but the first description of it was by Tolnay in 1799. Since that time, white scours, under various names, is frequently mentioned in veterinary literature. Its etiology was brought to light by Jensen (1891), Poels (1899), Joest (1903), Titze and Weichel (1909) and others.

Dysenteria neonatorum constitutes a problem wherever animal husbandry is carried on in an intensive manner, and there, in particular, it is apt to manifest itself in formidable stable outbreaks. The disease frequently shows a tendency to cling to certain stables and premises, where it has to be reckoned with every calving season. In some stables, all calves born are carried off by the malady.

As its name indicates, the disorder particularly affects the new-born, and in the more common form, caused by *Bacillus coli commune,* it declares itself during the first 1 to 4 days of post-natal life. In some instances, clinical evidence of scours becomes manifest within a few hours after the animal's birth.

Depending on the etiologic factor principally concerned, the diseases may make its appearance at a later period, but cases developing in animals more than 8 to 10 days old are relatively rare.

Clinically, white scours manifests itself by lassitude, loss of appetite and abdominal pain expressed by restlessness, bawling and straining. The feces early become fluid and fetid, and are often of an abnormally light color. They commonly contain undigested curds of milk, are frequently frothy and occasionally mixed with blood. There is tenesmus, tenderness over the abdomen and a very marked degree of weakness.

In the cases caused by *B. coli* infection, the body temperature may be only slightly increased and tends to become subnormal toward the end, death usually occurring within 1 to 3 days. Sometimes metastatic joint infections are observed.

The form of the disease caused by the paratyphus infections is apt to involve calves of more than 8 days of age. In such cases, fever is more apt to be part of the clinical phenomena and temperatures as high as 105° F. may be observed. In diplococcus infections the malady may occur in calves 2 to 4 weeks old. In all forms of white scours the mortality rate is very high, commonly amounting to 80 to 90 or 100 per cent of the animals affected.

The carcasses of animals dead with white scours are often characterized by a high degree of body waste. In practically all forms of the disease, there is evidence of a more or less severe gastro-enteritis. The mesenteric lymph nodes are swollen and may show small hemorrhagic foci. The serosa also may present hemorrhagic areas. Enlargement of the spleen is observed in *B. coli* infections, but this is a more constant phenomenon in cases caused by paratyphus bacilli. In the latter, the liver is usually enlarged, the organ containing numerous small, yellow foci, and the kidneys may show hemorrhagic areas. Pulmonary involvement is not uncommon in this form of the disease. In all forms of dysenteria neonatorum, the carcasses often present the aspects common to all the acute septicemias.

The disorder is of the highest economic importance, owing to its high mortality rate, often combined with a marked morbidity in the stables or establishments concerned. With the growing tendency, in the control of such disorders as abortion disease, tuberculosis and paratuberculosis, to depend on healthy, unexposed young stock, the great economic importance of a disease so disastrous to young animals cannot fail to become increasingly recognized.

Susceptible Species.—White scours is most frequently observed in calves, but is also encountered in new-born foals, lambs and pigs. The susceptibility to the disease shown by the new-born is a very conspicuous one, although transitory in character. Most animals more than 4 weeks old, when exposed in badly infected environments, fail to become involved in the common forms of the disease.

The Etiologic Factors of White Scours.—In its etiology, white scours does not constitute a distinct entity among animal diseases. Several bacterial species may be found to have causal relations to the disease.

The disease seems to be more an expression of the utter helplessness and of a complete vulnerability to almost any microbic invasion on the part of the animal organism than of a specific susceptibility. The first micro-organism, capable of a rapid multiplication, that comes along

and finds the tissues unprepared to meet the assault seems to succeed in the invasion of the body and in upsetting its vital functions.

If this hypothesis is representative of what actually takes place in the initial phases of white scours infection, it is not surprising that in the majority of the cases the ubiquitous *Bacillus coli commune* is found to be the etiologic factor.

Other microbic species which have been identified as relatively frequent causes of the disorder are: *Bacillus enteritidis* Gärtner, *Bacillus paratyphus B*, a diplococcus resembling *Diplococcus lanceolatus* of Fränkel, and *Bacillus lactis aerogenes*—most of them apt to occur as harmless saprophytes in the intestinal tract of normal adults and by them eliminated with the feces. In addition to these, *Bacillus pyocyaneus, Bacillus proteus mirabilis* and *Bacillus abortus* may apparently play a part as primary etiologic factors.

Bacillus coli commune and *Bacillus enteritidis* apparently account for most of the cases. The former, when isolated from diseased, new-born animals, cannot be differentiated by bacteriologic methods from the colon bacillus constantly present in the normal intestine. The organism associated with white scours, apparently, is greatly exalted in virulence by passage from animal to animal and then exhibits a marked degree of pathogenicity when injected in, or fed to, healthy new-born calves.

The microbic causes of white scours can readily be isolated from the intestines and the mesenteric lymph nodes of the animals dead with the malady, and in the majority of the cases from the other organs as well.

Although most of the microbes identified as causes of dysenteria neonatorum show but feeble resistance to certain external influences, they tend to cling to stables, once infected, with a high degree of tenacity and have been shown to maintain themselves there for 2, 3 or even more years, in spite of the fact that calves may not have been born there during intervals of 6 months.

It was found that in bovine feces containing Gärtner and paracoli bacilli the organisms were still demonstrable after a lapse of 10 to 11 months.

To the ordinary disinfectants, the microbes of white scours exhibit but a feeble resistance and readily succumb to their action. They are killed within a relatively brief period when exposed to temperatures of 55 to 60° C.

Modes and Vehicles of Infection.—White scours has not infrequently manifested itself in herds and stables which up to that time

had remained exempt from the disease and where no history of outside contacts could be elicited.

In view of the ubiquity of the micro-organisms more commonly associated with the malady and more or less endowed with at least a potential pathogenicity, it seems permissible to assume that, when they find their way into a particularly vulnerable animal, they increase in a prodigious manner in the gastro-intestinal tube and that from there they invade the more remote tissues and organs.

In the course of such an invasion, such organisms as the colon bacillus, *per se* not of manifest pathogenicity, assumes a virulence which soon becomes exalted to a high degree and which enables them to initiate regular outbreaks and to propagate themselves as long as new-born animals become periodically available. The virulence thus acquired appears to be an enduring one, and as already pointed out, the presence of bacteria thus equipped may render a stable a hazardous place for the new-born for extended periods.

The *Bacillus coli commune* isolated from calves affected with white scours, when injected subcutaneously into healthy new-born calves, has produced the disease in a number of experiments. When cultures of the organisms are administered *per os* or even *per rectum* there usually results an infection which cannot be distinguished from the spontaneously occurring dysenteria neonatorum.

In the naturally acquired disease, the infection is generally accepted as one of alimentary origin. Such an infection may come about even before delivery is completed, by the young swallowing the polluted mucus of the maternal vagina. Probably more common is the postnatal acquisition of the disease by nursing on a contaminated udder.

This contamination may pertain to the teats soiled with fecal matter or to the colostrum in cases in which the micro-organisms have found a habitat in the mammary gland itself. The latter phase of the problem has not been thoroughly explored, although the influence of the bacterial flora of normal and abnormal udders cannot readily be rejected.

Hand feeding from unclean vessels and contact with the soiled hands of attendants also plays a prominent part in transmission. Infection brought about by the licking and the mouthing of various objects in a polluted stable must also be given thorough consideration, fecal matter being largely responsible for such pollutions.

The umbilical stump may also serve as a port of entrance for the microbes associated with white scours, and the possibility of intra-

uterine infection must be admitted. There is, however, but little agreement with reference to the relative frequency of this mode of infection. Many authors consider it as of rare occurrence, whereas Williams, Hagan and Carpenter regard calf scours as fundamentally an intra-uterine infection although freely admitting the part played in post-natal infections by unclean methods of feeding. In the cases of dysenteria neonatorum in which the *Bacillus abortus* could be shown to be the etiologic factor, prenatal infection can be accepted without reservation.

In the other forms of white scours, intra-uterine infection cannot be conceded to be of common occurrence. The fact that when cows of more or less permanently infected stables are kept at pasture and deliver their calves there, the latter commonly enough escape disaster, remains as a point in favor of the extra-uterine origin of the malady.

The causative micro-organisms are eliminated from the body by means of the feces and the urine.

Factors Favoring Infection.—Of all the factors which favor the occurrence of dysenteria neonatorum, the one of age is predominant over all others. Only during the earliest phases of post-natal life are the animals liable to become involved in the disorder. The phenomenon must be associated with the extreme vulnerability of the intestinal mucosa to bacterial invasion. The permeability of the structures concerned combined with the lack of protective substances in animals of tender age render a microbic assault particularly hazardous.

In the face of such a situation, even non-pathogenic colon bacilli appear to be able to swarm into the tissues. When, after doing so, they acquire a distinct virulence, all exposed new-born calves are apt to become infected.

A manifest influence on white scours morbidity is associated with the environment. The disorder does not occur, or is extremely rare, among animals born at pasture, and livestock which, under conditions of semi-domestication, remains at pasture, or on the open range, is practically exempt from this type of infection.

That the disorder has been observed to declare itself particularly during spring and autumn cannot be attributed to seasonal influences *per se*. More important in this connection is the fact that during these periods parturient animals are more apt to inhabit stables than to be found at pasture. The phenomenon merely emphasizes the influence of stabling on the incidence of the disease.

Predispositions associated with a lowered resistance, by dietary

errors, by chilling and by similar factors have often been recognized. It is, however, quite doubtful that the resistance to bacterial invasion of the new-born is capable of being reduced. In all probability it is always a negative quality in such animals at the time of birth, and certainly so before the event.

On the other hand, there can be no doubt that, although it is impossible to reduce a negative resistance, faulty feeding may, nevertheless exercise a most potent influence in promoting infection. Thus, the withholding of the colostrum is by many authors correctly estimated to constitute a very important predispositional factor.

The colostral milk can be shown to contain specific antibodies for the organisms etiologically associated with the malady. It is a means, and most probably the only one, by which the maternal body is capable to confer to its young a measure of resistance against the microbic elements by which it becomes invaded soon after birth. Hence, the substitution of boiled milk for colostrum as an animal's first nourishment has often proved to be disastrous. Such a practice leaves the animal without any protection at a time when its vulnerability is the most pronounced.

Prophylaxis.—The prevention of white scours, attempted by various methods and approached from many angles, has not constantly or uniformly been successful and as yet constitutes a problem only partially solved.

The ubiquity of the microbic causes, their high degree of acquired virulence, their tenacity in clinging to infected stables, combined with the extreme vulnerability of the animals concerned, continue to supply serious obstacles to an effective prophylaxis. Nevertheless, it is possible to deduce from the evidence made available in literature certain principles, the application of which may prove useful in livestock sanitary practice.

Owing to the potency of the environmental factor in the etiology of white scours, weight must be given to the value of the hygienic construction and management of the stable. Although even under the best of circumstances the stable cannot always be made safe for the new-born, the importance of cleanliness and disinfection must not be so under-estimated as to lead to neglect.

At least, maternity stalls may be provided where the young can be born and receive their initial care under the best possible hygienic conditions. A space may be set aside where the new-born can be housed without contact with the soiled objects commonly present in

the average establishment. In the case of recurring outbreaks, the stable may have to be abandoned by parturient animals and breeding operations so timed that the young can be born at pasture.

Wherever a white scours hazard has to be faced, particular care should be bestowed on the parturient animal. She should be placed in a clean and disinfected stall, and prior to delivery the external parts with which the calf may come in contact should be thoroughly cleansed and disinfected.

The young should be received on a clean cloth or sheet and immediately removed to a clean place prepared in advance. The new-born should be dried and the parts adjacent to the mouth freed from mucus and such other material as may be present there. The navel stump should be disinfected without delay, using an iodine solution for the

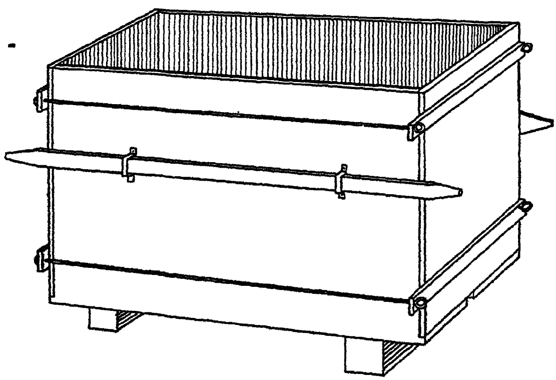

FIG. 74.—Calf box. (After Evers.)

purpose. By the use of a clean and appropriate muzzle, the animal should be prevented from licking or mouthing any object present.

In questionable environments or where no special space can be set aside, the use of calf boxes as proposed by Evers may offer a special safeguard. These boxes are constructed of smooth lumber, measuring 5 feet in length, 3¼ feet in height and 16 inches in width. They have solid sides, but are open at the top and are so made that they can be readily taken apart for cleaning and disinfection. They are painted within and without, and provision is made for draining away the liquid ejecta. They are bedded with clean straw, or still better, with peat moss. The calf remains in this box for 4 to 6 days, the period of maximum vulnerability.

Immunization.—Since the initial experiments of Jensen with im-

mune serum prepared by the use of the microbic agents of the malady, its use has found a wide application, and in many instances have calves been saved by the passive immunity thus conferred.

In view of the fact that the biologic causes of the disease include many specific forms, constant results can, however, not be expected from serum injections administered as a matter of routine practice. For maximum results the etiologic factors should be previously determined, and this procedure should find application in stables where the disease is enzootically established.

Even when the appropriate antiserum has been used the results have not always come up to expectation, and those following the routine use of stock sera are always uncertain.

If the previous identification of the microbic cause of white scours could not be made in time, the injection of substantial doses (200 c.c.) of the defibrinated blood of the dam would probably be fully as useful, empirical as this method of protection may be.

Whatever the choice of a serum may be, it is imperative to make the injections as soon as possible after the birth of the animal to be protected, and there may be advantage in repeating the injections at 10- or 12-hour intervals.

The value of active immunization by the use of vaccines or bacterins is doubtful, owing to the tardiness of the development of the active immunity.

Attempts have been made to protect the calf against post-natal white scours by immunizing it while still *in utero* by an appropriate treatment or vaccination of the dam during the last months of pregnancy. The premise upon which such a procedure was based was faulty, because the bovine female cannot cause its fetus *in utero* to share in the specific antibodies found in her own body or even in those introduced from without. Such substances do not traverse the placenta and hence cannot benefit the calf. In addition, the immunization of the cow is always accompanied by a certain hazard.

The Colostrum.—The only means by which the maternal animal can confer a degree of protection to her offspring is the colostrum. Smith and Little and Traum have clearly shown that the colostrum secreted during the first two days contains antibodies which protect calves against *Bacillus coli commune* and that they are readily absorbed as such by the new-born during the first phases of post-natal life.

That the colostrum had an influence tending to safeguard the young was already a matter of empirically acquired knowledge, and

the experimental results of the investigators cited above confirmed these earlier observations and indicated the fundamental reason.

As the protective substances of the colostrum rapidly diminish, it seems proper that the new-born be fed with colostrum shortly after its birth. In an infected environment, hand feeding should be preferred in order to avoid more completely all contact with soiled parts of the maternal body surface. Before the collection of the colostrum, the udder, the teats and adjacent parts are to be thoroughly cleaned and disinfected. The first strippings should be discarded, and of the colostrum subsequently obtained, about a half a pint may be given to the calf from a sterilized nursing bottle, and a similar quantity can be allowed an hour or two later.

It is obvious that the hands of the milker or attendant must be scrupulously clean and that the colostrum should be fed immediately after its withdrawal from the udder. In the case of very large calves a third feeding, 4 or 5 hours after the second one, may be permissible, although this is not absolutely necessary.

For some 20 to 24 hours after the last feeding, no more colostrum needs to be given. After the termination of this period, regular feeding may be cautiously commenced, feeding from 3 to 5 pints per day, divided over 4 or 5 feeding periods. If no evidence of digestive disturbances becomes manifest, the daily ration may be gradually increased.

If the use of sterilized or pasteurized milk is indicated, this must, under all circumstances, be delayed until at least 2 days after the last colostrum feeding of the first day, and all milk must be fed at body temperature.

It is quite obvious that the udder of the dam supplying either colostrum or milk must be a sound one. If, on account of mammary infection, the colostrum has to be rejected, the calf may, to a degree, be protected by an injection of the defibrinated blood of the dam, or of some other healthy lactating cow of the same herd, some hours prior to the first feeding with milk.

Experimental results reported by Smith and Little indicate that the addition of cow serum to the milk, in combination with the subcutaneous or intravenous injection of normal serum, may still further increase the safety of exposed calves.

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CHAPTER XXXIII

SWINE ERYSIPELAS

SWINE erysipelas began to attract the attention of swine growers early in the nineteenth century. It must have occurred prior to that period, but it was not established as a separate and distinct disease of swine until relatively late. Before the development of bacteriology as an aid to diagnosis, the disease was commonly confounded with anthrax and other acute infections.

Swine erysipelas is a transmissible disease caused by a specific virus and manifesting itself in four distinct forms: (1) as an acute septicemia, (2) as a more benign urticaria (diamond skin disease), (3) as a chronic valvular endocarditis and (4) as a necrotic dermatitis.

The septicemic form is the most formidable, and this, with its characteristic hemorrhagic patches of the skin, discrete or confluent, is that to which the current name is especially applied. The skin manifestation of the septicemia form may be absent in certain per-acute cases referred to by French authors as "Rouget blanc."

The septicemic type of swine erysipelas is marked by a high mortality rate which ranges from 60 to 100 per cent of the animals affected with an average of approximately 75 per cent.

The disease is especially prevalent on the European continent. In Great Britain as well as on the Scandinavian peninsula it is less common, and when it does occur there it does not appear to be capable of disseminating itself in the manner observed in the continental countries. However, attention has lately been called to the fact that swine erysipelas is becoming more common in England. It has also been observed in the United States, but it has, thus far, not established itself in definite foci on the North American continent. There are indications that it may be more frequently encountered in Mexico.

The geographic distribution of the disease shows peculiarities which, at this time, are not fully understood. They appear to point to factors as yet unknown, which play a part in the epizootology of the disorder. Even in countries where the disease is quite common, regional influences seem to be at work. There are districts where swine

erysipelas is enzootic, and although from such centers the disease may spread to adjoining territory, secondary foci, so formed, do not always persist.

Sometimes the disease suddenly breaks out in a hitherto exempt territory causing enormous losses within a few weeks. It is, however, uncommon that the infection thus becomes permanently established in new areas. It may rage there to the close of the warm season and then disappear, not to return again. Only occasionally is a new, permanent infection center established in such an area.

It has been observed that it habitually occurs in a benign form in certain districts, whereas in others it is commonly characterized by a marked malignancy.

The Virus of Swine Erysipelas.—The etiologic factor of swine erysipelas is the *Bacillus erysipelatis suis,* an organism with which the bacillus of mouse septicemia appears to be identical, morphologically as well as culturally.

These organisms, probably represented by several strains, are ubiquitous in certain regions. They occur as saprophytes in the soil, in manure and in surface water. They are facultative parasites, and some of the better-known strains, at least, may be quite virulent. Their possible relation is certainly suggested by the fact that in the countries of the European continent, where the microbe of mouse septicemia is of common occurrence, swine erysipelas is also prevalent, whereas in this country, where the latter disease is very rare, the bacillus of mouse septicemia is but seldom found.

The bacillus of swine erysipelas can be readily demonstrated in the blood, the subcutaneous lymph spaces, the subcutis, the cutaneous patches, as well as in the lymph nodes of the acute cases. It is likewise to be found in the lesions of the more benign and chronic forms of the disease.

In the regions in which the disease is more or less enzootic, the organisms frequently occur in the pharynx, the tonsil and the intestines of normal swine. Bacilli apparently identical with the one causing swine erysipelas have been found in cattle, in lambs, in colts (arthritis), in poultry and in other birds. The pathogenicity of the organisms is variable even for swine. Pure cultures in such small quantities as a $\frac{1}{1,000,000}$ c.c. of a bouillon culture, are readily fatal to white and gray mice. Pigeons are scarcely less susceptible and are killed within 2 or 4 days when inoculated with similar quan-

tities. Rats and rabbits are more resistant, although in the latter the inoculation is apt to cause redness and swelling at the point of injection and the animal may succumb as a result within 5 or 6 days.

Cavias, fowls, ducks, geese and the large domesticated mammals, with the exception of swine, cannot be infected by inoculations or by the ingestion of the microbes. It is, however, not impossible that certain microbic strains are virulent for at least some of the animal species mentioned. One investigator was successful in infecting fowls artificially, but there appears to be no evidence which shows that this specific pathogenicity was at all increased by subsequent passage.

On the other hand, it is certain that repeated passages through swine materially exalt the virulence of the microbes for this species. Passage through pigeons increase the virulence for mice, but the virus becomes attenuated for swine when passed through rabbits. Continued cultivation also tends to diminish the virulence. The pathogenicity of the organism may be a somewhat complex phenomenon as there are indications that the bacilli have the power to initiate aggressive actions in the living animal body.

The bacillus of swine erysipelas is quite resistant to adverse, external influences, and this resistance appears to be associated with certain waxy substances present in the bacillary structure.

In common as well as distilled waters the microbes may remain alive for considerable periods; they were found to be alive after being kept in suspension for respectively 17 and 34 days. In certain places where the soil was moist and where stagnant water was present, the organisms not only remained alive, but they actually multiplied in the manner of saprophytes of the soil.

The swine erysipelas bacilli are but slowly killed by drying, and when exposed to daylight at 37° C. they remained alive for 12 days. If the light is excluded, the organisms persist in a viable form for a week longer. Kept in a cool place and in the dark, while smeared on glass slides, the microbes remained alive for a period of 4 weeks.

The germs are more vulnerable to higher temperatures and when kept at 44° C. they perished in 4 days. A temperature of 70° C. destroys them in a few minutes.

In acid soil the organisms die relatively soon, but in alkaline soil they apparently can maintain themselves for prolonged periods. This sensitiveness to differences in the reaction of the ambient media may, in a measure, explain the peculiar variations in the morbidity observed in different regions.

The bacilli are capable to survive for weeks and months when con-

tained in putrefactive material. Apparently they are able to multiply in fecal extracts, and when kept at room temperature for 13 days they grew through 4 inches of sterile earth without manifest changes in virulence. In buried carcasses they have been found to remain viable for months (280 days), although it must be remembered that the resistance of bacteria in general is influenced by so many factors that evidence pertaining to tenacity may often be quite contradictory.

From a livestock sanitary point of view it is important to consider that in smoked and salted meat the bacilli remain viable and virulent for prolonged periods. Pieces of meat kept in brine for 170 days, in a mixture of salt and saltpeter for 30 days or smoked for the same length of time may yet contain virulent organisms. In smoked ham they were still alive after 3 months. Pieces of meat 6 inches in thickness apparently require cooking for 2½ hours before a complete sterilization is secured.

The swine erysipelas microbes are readily destroyed by the disinfectants in common use, although the media in which they happen to be contained may, in a large measure, determine the length of the period of exposure required for their destruction. Five per cent solutions of phenol and of the saponified cresols destroy the virus in about 15 minutes. Exposure for 4 hours to formaldehyde vapor is sufficient to kill the organisms, and they rapidly succumb in a hot lye solution (1 per cent) and in one of iron sulphate (3 per cent), hypochlorite of lime (1 per cent), copper sulphate (0.25 per cent), and of sublimate (0.1 per cent).

Host Species.—Although the bacillus of swine erysipelas has, on occasions, been found in several animal species, including man, the spontaneous disease, as a problem in livestock sanitation, practically occurs in swine only. In this connection, the fact that mice are apt to become naturally infected by what appears to be an identical microbic form must also be given consideration.

Modes and Vehicles of Infection.—In the spontaneous infection the virus most commonly finds its port of entrance in some part of the alimentary tract. This may be associated with the pharyngeal mucosa, the tonsil or the mucous membrane of the intestine. Once the bacilli have penetrated into the tissues or entered the lymph spaces, they are rapidly disseminated by the general blood circulation or transported to the blood stream by means of the lymph.

Abrasions or wounds of the skin may also serve as entrance portals, although this mode of infection is probably not a common one. Respiratory infection is of doubtful occurrence.

After a rather brief period of incubation, usually 2 to 4 days, the disease manifests itself, and the virus is again eliminated quite early in its course. The intestinal evacuations, as well as the urine, supply the media in which the bacilli find their way into the environment. There the pollution of food and drinking water supplies the means of spread to other animals, although meat products and slaughter offal, as well as carcasses of swine dead with the disease must be given consideration as vehicles for infection. The latter does not appear to be transmitted by the air.

The transportation of infected swine commonly accounts for long-distance transmission of the disease. It is possible that other animals also may serve as infection carriers, at least, mice infected by, or dead with, mouse septicemia must be regarded with suspicion, especially in districts where swine erysipelas commonly occurs. Butchers, pig gelders, hog buyers and the like may also serve as distributors of infection, and institutions like shows, fairs and swine markets may prove to be very potent in the dissemination of the disease.

In infected territory, the soil, no doubt, serves as a virus reservoir. A definite infection hazard is associated with pastures which were previously occupied by diseased swine, and land fertilized with the manure derived from hog establishments is particularly dangerous for prolonged periods.

A more or less permanent pollution of the soil accounts for the fact that on certain farms the disease may constitute a perennial problem, the virus evidently surviving from one outbreak to another.

The dissemination of swine erysipelas is particularly favored by continued rainy weather, the abundance of surface water furnishing an excellent means for virus transportation.

Although there can be no doubt that the virus derived from actual outbreaks of the disease are mostly responsible for its occurrence on account of their pronounced degree of virulence, the so-called "wild," avirulent or merely saprophytic strains cannot be dismissed as entirely harmless. Such microbic forms have been found to be capable of causing the urticarial form of the disease.

Under favorable circumstances, such as marked susceptibility on the part of the swine exposed, such strains may, by repeated passages, assume a more virulent character. The swine erysipelas bacilli present in normal swine may also acquire mischief-producing qualities and must be taken in account when infection sources are a subject of inquiry.

Factors Favoring Infection.—The possibility of swine erysipelas

outbreaks is favored by a filthy and otherwise unsanitary environment, as by its influence the chances of food and water contamination are increased. The character of the soil itself may have an influence on the epizootology of the disease. Apparently an open, sandy soil is less favorable to the occurrence of swine erysipelas than the clay of low, rich bottom lands, where water is apt to be retained on the surface and in the structure of the upper soil layers.

The seasonal influence on swine erysipelas morbidity is a very conspicuous one. It is essentially a warm weather disease, which is apt to assert itself when the higher temperatures prevail. With the advent of summer the disease gains in virulence and intensity, to recede again when autumn sets in. During winter and early spring it occurs either sporadically or not at all. The highest morbidity rates are observed between May and September in the northern hemisphere, but occasionally considerable losses have been sustained even in winter.

Among the factors which favor swine erysipelas infection, that of age is a dominant one. Pigs less than 3 months old show a minimum of susceptibility and have been demonstrated to resist inoculations capable of killing adult hogs.

When exposed to direct contact, young pigs escape the disease altogether or contract it in its more benign form (urticaria). Only in outbreaks marked by an extreme degree of virulence, may they succumb in the manner of older swine. In the recorded outbreaks of this type, however, it has not always been possible to exclude other intercurrent infections (hog-cholera, pig typhus).

The susceptibility to swine erysipelas becomes less after a certain age has been reached, and apparently it diminishes progressively after the age of one year has been passed. It would, on the other hand, not be prudent to place too much reliance on this phenomenon because the resistance may be entirely due to a degree of immunity acquired by exposure during the juvenile period, and such an exposure may not always have taken place.

Prophylaxis. *General Measures.*—In the prevention of swine erysipelas the measures to be adopted are largely determined by the epizootic character of the disease in a given region as well as by the prevailing morbidity rate. The problem in a territory free from the disease, or relatively so, has entirely different aspects from one which constitutes a hot-bed of infection. In a country like the United States, the disease may as yet be ignored, but in many districts of the European continent, on the other hand, it calls for the most energetic efforts perennially applied to the problem.

The maintenance of a sanitary status of environment and the practice of a sound animal husbandry, no doubt, are material aids in prophylaxis, as in many other transmissible diseases. However, in the case of swine erysipelas, when confronted with a positive infection danger, mere sanitary measures will commonly fail to accomplish the desired results, no matter if they have a definite place among control measures.

Sound feeding practices have a similar value, and these should certainly include a late weaning of the pigs inasmuch as experience shows that pigs weaned early, as a rule, sicken more readily than those weaned late.

In a disease-free territory, efforts in prophylaxis should principally consist of the exclusion of swine originating in regions where the disease is prevalent. Restrictive measures of this kind should include meat products of unknown or questionable sources, and possible carriers of infection should be prevented from supplying indirect contacts to healthy swine. If recently purchased swine are to be introduced, they should be kept in segregation for observation purposes for a period of not less than 2 weeks.

Pastures or other enclosures in which the disease occurred should remain unoccupied by swine for a prolonged period (not less than a year). When swine erysipelas makes its appearance in a herd, the diseased and healthy swine should at once be segregated. The latter should be moved to quarters not contaminated by the body wastes of the sick, and if there they could be divided in several separate small groups this would be a further advantage. Carcasses of animals dead with the disease should be adequately cremated, and wherever disinfection can be effectively practiced this should be done.

On the whole, however, the experience accumulated in infected territory tends to show the futility of sanitary police measures and of the practice of disinfection, and there is reason to believe that the saprophytic nature of the virus may be an important influence helping to make control by sanitary efforts so difficult. As in hog-cholera, little can be accomplished without recourse to artificial immunization.

Immunization.—In the more or less permanently infected regions, the practice of artificial immunization is the only means of prevention that can be effectively utilized against swine erysipelas, even if the possibility of establishing a marked resistance to the disease has not contributed to a definite eradication. Theoretically the vaccination of an entire swine population may be expected to bring this about, but such an attempt has thus far not been made. The

widespread distribution of "wild" strains of the organisms and the possibility of their assuming pathogenic characters are factors which may materially interfere with any plan of eradication, no matter by what means.

The practice of vaccination, no doubt, is a safeguard of prime importance, and in the countries most damaged by the disease it has prevented great losses which, without it, would have been inevitable.

Various methods, differing more in technical details than in principle, have been found to be useful, although not all of them are now regarded with favor.

Some authors even attribute increases in the prevalence of swine erysipelas to the practice of vaccination, inasmuch as live cultures of the causative microbes must be used if an active and lasting protection is to be secured. As immunization practices are almost exclusively confined to more or less permanently infected territory, where the bacilli are widely distributed in soil and manure and where healthy swine commonly harbor them, the validity of the objection mentioned does not appear to rest on solid ground.

Whatever method is employed, the protective inoculations should be made during the spring of the year and before the advent of warm weather.

Pasteur was the first to devise a method of vaccination by which protection against swine erysipelas could be secured. His method, particularly applicable to pigs 2 or 3 months of age, consists of the inoculation of two vaccines of different degrees of attenuation. The vaccine I is practically avirulent, the component microbes having been attenuated by passage through rabbits. Vaccine II, composed of virulent organisms, is injected about 12 days later. The inoculations are made subcutaneously, and immunity is established 2 or 3 weeks after the last inoculation. The duration of the resistance thus acquired is estimated as extending over a period of from 6 to 12 months. When it is desired to extend the protection over more than a year the vaccination must be repeated at the end of the period mentioned.

Older swine are to be vaccinated by the Pasteur method only if they were not already treated when they were pigs, and sows in advanced pregnancy or during the lactation period should be excluded from the process.

The initial results with the Pasteur method were apparently quite favorable, but in time vaccination losses were reported which tended to render the method unpopular. In some instances, these losses were

so high that, in spite of the solid immunity which is often established, the method has been largely abandoned. It was superseded by sero-vaccination.

This method bears the name of Lorenz, who introduced it in practice. The required active immunity is secured by the inoculation of a small quantity of virulent culture of the swine erysipelas bacilli. In this respect, the principle is the same as that underlying the Pasteur method. However, it differs in this particular, that the necessary protection for the animal to be immunized is provided not by a first vaccination with an avirulent vaccine, but by a simultaneous injection with immune serum.

This method is now the most generally used in the countries where the disease has to be combated with immunization methods. With a marked degree of safety and efficiency it combines the advantages of bringing about protection from the first day on. It can be used in animals of all ages. The duration of the immunity conferred is estimated at 6 months, but if a more lasting protection is desired, this may be secured by a second injection of virus made from 10 to 14 days after the simultaneous sero-vaccination.

A similar method of vaccination was designed by Leclainche. In his method the virus and the serum are mixed immediately before use and the mixture is injected at one point and as one operation. About 12 days after the injection of the serum-virus mixture another one with virus only is made. The results obtained with this method have been satisfactory. It obviates the use of two syringes, and, to this extent, it simplifies the vaccination technique.

The use of virus is not warranted when swine are already sick with the disease; on the other hand, serum alone has frequently been shown to possess marked curative properties. In actual outbreaks, serum injections are of advantage, but they should be followed by the simultaneous sero-vaccination when the disease has receded.

All methods of immunization of which the use of virus forms a part should be confined to regions where swine erysipelas is a frequent or permanent problem. They have no place in territory where the disease does not commonly occur.

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CHAPTER XXXIV

CONTAGIOUS BOVINE PLEUROPNEUMONIA

CONTAGIOUS bovine pleuropneumonia, peripneumonia, lung plague or lung sickness is a transmissible disease of cattle, characterized by an exudative inflammation of lung and pleura and caused by a specific virus.

The disease tends toward a chronic course, although an acute behavior is occasionally observed. It is marked by a rather prolonged period of incubation at the termination of which an elevated body temperature and a rather indefinite pulmonary impairment declare themselves. Within a few weeks the latter assumes the aspects of chronic lung involvement accompanied by a cough, difficult and labored breathing, painful movements and marked loss of weight.

The pulmonary and pleural lesions consist of a sero-fibrinous exudate in the interlobular and subpleural connective tissues, which confers upon the cut surface of the affected lung a more or less typical marmored appearance. There is solidification of the lung tissue with a tendency on its part to become necrotic and to form sequestra.

Lung sickness is marked by a high rate of mortality, estimated to range between 30 and 70 per cent; moreover, the recoveries are, to a considerable extent, more apparent than real, on account of the persistence of chronic, permanent lesions.

How long the disease existed before it could be recognized as a distinct, specific one is not known. The first description of a fatal, pulmonary affection of cattle regarded by certain authors as being identical with the disease under consideration dates from 1693, when Valentini, a chronicler of Hesse, made mention of a lung disease, epizootically prevalent and accompanied by a very high death-rate. Bourgelat in 1769, and Haller in 1773 were the first clearly to depict the disorder as it is known at the present time.

From that time on, contagious pleuropneumonia has been recognized as one of the major scourges among cattle of the old world, causing severe losses wherever it was introduced. Between the years 1827 and 1846, it was responsible for a loss of not less than 212,800

cattle in the French Department du Nord. In the period 1835–1845 it caused the death of 100,000 animals in the Rhine province of Prussia, and between 1830 and 1840 a loss of 64,000 head of cattle could be attributed to lung sickness in the Netherlands. In the single year 1860 more than 18,700 cattle succumbed to it in Great Britain.

About the middle of the nineteenth century peripneumonia was introduced into the more remote parts of the world. In the year 1854 it appeared in Massachusetts and in South Africa, and Australia witnessed its introduction in 1858.

Susceptible Species.—The susceptibility to contagious pleuropneumonia is limited to cattle and to such more or less allied species as the camel, bison, buffalo, yak and reindeer. Sheep and goats have apparently been infected by artificial inoculation, but the few isolated experiments do not warrant the conclusion that these animals are apt to play a part in the transmission of the natural disease.

The majority of observers have always regarded sheep and goats, as well as man, horse, swine, various carnivora, rabbits, guinea-pigs and birds, as refractory to the infection.

Epizootological Considerations.—Unless actively opposed by rigorous livestock sanitary police measures, contagious pleuropneumonia is apt to maintain itself in a given region in an enzootic form. From such a more or less permanent focus its spread to new territory follows the channels of cattle trade. Diseased or infected animals are the carriers of the virus; countries receiving no cattle importations, as a rule, remain free of the disorder.

After its introduction, the behavior of peripneumonia in a given herd or stable may show considerable variation. Frequently all the stock sicken within a few weeks after the initial contact, but in other instances the progress of the infection may be drawn out over a considerably longer period. In such cases, the visibly affected animals may constitute only a relatively small portion of the total number. In the larger herds, several months may elapse before all the susceptible animals have become involved. On the other hand, outbreaks of an epizootic character have not been rare.

After the disposal or death of the last clinical case, an infection hazard is apt to remain for 3 or 4 months, or even longer. The infectivity of the incapsulated lesions of apparently recovered cases may continue for not less than 15 months.

Once the disease has gained a foothold in a given bovine population it may continue as a more or less serious menace for many years unless the most radical measures of eradication can be applied.

In this country, where the disease was introduced about the middle of the last century, its progress remained unchallenged for about a year. Even after this period, the efforts directed against it were somewhat desultory in character. As a result, not less than 11 states became involved in the outbreak, and it was not until nearly half a century later (1892) that the infection was finally disposed of.

The Virus of Pleuropneumonia.—Variously known as *Asterococcus mycoides, Coccobacillus mycoides peripneumonia, Micromyces peripneumonia bovis contagiosa* Frosch, the virus of lung plague consists of a very small, non-motile, polymorphous micro-organism, filterable, but yet visible at magnifications of 1500 to 2000 diameters. It was discovered in 1898 by Nocard and Roux, who succeeded in cultivating it in an artificial medium.

Under natural conditions the microbe apparently grows only in the characteristic lesions of the lung and pleura. The exudate of the interlobular tissues of the lung and of the pleura as well as the contents of the alveoli and bronchi is always virulent. It can at times be demonstrated in the lymph nodes which receive the lymph drain of the involved tissues. The virus is present also in the sequestrated and incapsulated parts of the lung, where it may retain its virulence for long periods.

The earlier investigators failed to show its presence in the blood, feces, milk or urine of the affected animals. More recently the virus was shown to be present in the liver, spleen, kidneys, lymph nodes and joints. It was also demonstrated in the circulating blood of affected cattle, which appeared to be favorable to its propagation. The virus, according to later investigators, may be eliminated, aside from the respiratory discharges, by means of the urine, the milk and the lochia.

The virus of peripneumonia shows but slight resistance to external adverse influences, although in protected situations it may survive and remain virulent for considerable periods. The virulent lymph of the affected lungs aseptically collected and stored in sealed glass tubes retains its virulence for about a month, after which attenuation soon becomes evident.

Cultures kept in the incubator retain their virulence for no longer than 6 to 8 days. When renewed every 2 weeks and stored in a cool place they may remain virulent as long as nearly a year. If constantly kept in the incubator the cultures loose their capacity for growth within 50 days; the ones stored in an ice chest or kept at room temperature showed evidence of attenuation in less than 110 days.

The virus of lung sickness does not appear to be capable of saprophytic existence. Exposed to air and sunlight, virulent material is already attenuated after 20 to 25 days. In the pulmonary exudate, as well as in the cultures, the virus shows but little resistance to desiccation.

The microbe is very vulnerable to heat. Cultures are sterilized in less than 1 hour by heating to 58° C.; on the other hand, frozen lung retained its virulence for more than 1 year. By more recently reported experiments it was found that at a temperature of 60° C. the virus contained in cultures was killed in 2 minutes; at 55° C. in 5 minutes; at 50° C. in 1 hour and at 45° C. in 4 hours. On the whole, the virus displayed a greater resistance to dry than to moist heat.

The peripneumonia virus shows a relatively feeble resistance to chemical disinfectants. A 0.125 per cent solution of cresol killed it in 10 minutes, but not in 5 minutes; a 0.25 per cent solution killed in 5 minutes, but not in 2½ minutes. On the other hand, a 0.25 per cent solution of formaline failed to destroy it in 90 minutes, but did so in 105 minutes. A 3 per cent solution killed in 15 minutes, but not in 10 minutes.

A proprietary chlorine preparation (containing 20 per cent active chlorine) in a 0.01 per cent solution killed the virus in 30 minutes, but not in 20 minutes. In a 0.02 per cent solution it was killed in 15 minutes, but not in 10 minutes. Another proprietary disinfectant (containing about 70 per cent chlorine) in a 0.01 per cent solution killed the virus in 15 minutes, but not in 10 minutes; however, in a 0.1 per cent solution it was destroyed within 1 minute.

Mercuric chloride (0.02 per cent) destroyed the virus after a brief exposure, but it required not less than 3 hours' exposure in a 0.5 per cent solution of carbolic acid to bring about the same result. To concentrated glycerin the virus appears to be quite resistant.

Modes and Vehicles of Infection.—Animals affected with lung sickness, regardless of the stage of the disease, constitute the source of the virus the transmission of which becomes responsible for its spread. How this transmission comes about is not known with any degree of accuracy, inasmuch as thus far it has not been possible to reproduce the disease in its classical form by any method of experimental infection.

As a consequence, opinions regarding the mode of infection are largely based upon empirical evidence. Chauveau succeeded in the transmission of peripneumonia to an experimental subject by placing

the latter opposite an affected animal and by connecting their heads by means of a sort of a tube made by wrapping cloth around them. This method of inducing the disease is practically equivalent to a more than usual intense natural exposure, and like the latter proved only transmissibility.

In other experiments, even the inhalation of virulent cultures failed to cause the characteristic form of the disease. A catarrhal condition of trachea and bronchi resulted, but this proved to be transitory and had disappeared in 1 to 2 weeks. Intratracheal injections of virus as well as its ingestion failed to reproduce the disease even when virulent pleural exudate and pulmonary lymph were used in these experiments. The intravenous injections of virulent exudate likewise failed either to cause disease or to establish immunity.

Although no one knows precisely by what mode or vehicle transmission comes about, a substantial volume of evidence indicates that it always follows the introduction of an infected animal into a healthy herd. There is much agreement among observers that the air passages serve as the primary port of entrance for the virus and that the latter is transported by the respiratory air.

Acutely affected animals are apparently the most prolific source of infection, but the chronic cases as well as the merely exposed cattle without clinical or pathological manifestations of lung plague are also able to transmit the virus. In some rare instances, evidence of intra-uterine infection was observed. In areas with a lively traffic in cattle, vaccinated animals are regarded as factors in the spread of the malady.

Prolonged, direct contact is most apt to bring about the transmission of the disease. The importance of brief exposures is minimized by certain observers, but others admit its possibility. Transmission by intermediary carriers has not been proved with certainty, although some of the earlier writers expressed the opinion that water, persons and small animals may serve as vehicles for the virus.

The length of the incubation period of peripneumonia varies greatly. It may range between 6 and 45 days. A period of about 2 weeks has frequently been observed.

Even though the reproduction of the typical or classical form of pleuropneumonia by artificial inoculation has not been achieved, the introduction of the virus into certain parts of the body is apt to result in striking, fatal reactions. Introduced into the pleural cavity, the virus gives rise to a sero-fibrinous pleuritis and peritonitis, ac-

companied by pulmonary infiltration and an acute lymphadenitis of the mediastinal nodes.

The subcutaneous inoculation of the virulent lymph of the lungs into the dewlap, the shoulder or other part of the body brings about a severe reaction expressed by extensive, hot, edematous swellings. The evolution of this reaction is a slow one. Its earliest manifestation is a rise of the body temperature (104 to 108° F.) about 5 or 6 days after the injection. The appearance of the swelling is commonly delayed for about 2 weeks more. From then on it develops rapidly, death following within 10 to 14 days after its manifestation.

The introduction of the virus into the udder causes a severe mastitis, accompanied by marked inflammatory phenomena and by edema of the perimammary tissues.

Factors Favoring Infection.—Although the bovidae are specifically susceptible to contagious pleuropneumonia, this susceptibility may show variations. Only a few animals in a herd may become affected while the remainder continue in good health. It is not certain, however, that this phenomenon may be entirely attributed to a definite individual resistance, and in view of the possibility of animals becoming infected without presenting clinical or pathological evidence of disease, the variation in susceptibility may be more apparent than real. The introduction of the more precise serologic methods of diagnosis may lead to conclusions different from those which have thus far prevailed.

Age apparently is a factor in the readiness with which animals contract the disease. The classical form of the disease appears to be rare in calves less than 5 or 6 months of age, although such animals may show articular or tendovaginal synovites as a result of their exposure to the contagion.

Environmental conditions seemingly influence the nature of outbreaks. In unsanitary stables permanently inhabited by cattle, the disease may show a rapid spread. This is probably caused as much by the close contacts as by other factors, for it is often observed that animals adjoining or facing one another sicken successively in series. Among cattle at pasture, the infection is more slowly disseminated.

The crowding of animals in insalubrious surroundings, in railway cars and ships, is a potent influence by which the spread of the disease is materially enhanced. An active commerce in cattle in the face of existing infection certainly constitutes the most active means of dissemination.

Prophylaxis.—An abundance of evidence shows that the eradication of contagious pleuropneumonia from a well-established focus of infection is not readily accomplished. As a disease largely propagated by direct contact only, it may reasonably be expected to yield to the various measures of prophylaxis. This, however, is not the case, principally because of its slow evolution, which renders a prompt and early diagnosis difficult, if not altogether impossible.

In the experience of the past, this, as well as the prolonged period of incubation peculiar to the disease, has always stood in the way of its prompt and final suppression. Infected animals could not always be recognized before they had served as contacts for other cattle, and non-clinical, or no-lesion virus carriers added their share to the obstacles confronting those engaged in the task of eradication. In spite of all efforts, the disease often stubbornly maintained itself in a given cattle population.

The acquisition of suitable serologic methods of diagnosis by Giese and Wedemann and others holds promise that the obstacles mentioned may be adequately removed. There is ground for the belief that the complement fixation test as well as the precipitation-agglutination test not only can materially supplement and support the clinical diagnosis, but may also permit the recognition of cases which even would escape detection by the patho-anatomic examination.

The value of these serologic methods may not yet have been fully established by experience in extensive outbreaks, but it is both significant and encouraging that one application of the complement fixation test alone revealed not less than 93 per cent of the cases, and that 83 per cent of animals with more or less extensive sequestra could be definitely recognized as being specifically affected.

In conjunction with established principles of livestock sanitary practice, the early recognition of infected animals should place prompt eradication within reach and should reduce the costs of the necessary efforts to such a degree that radical measures could be applied in regions where, thus far, only palliative attempts could be undertaken.

Once the disease is stamped out in countries with an effective livestock sanitary service, the continued freedom of infection may be assured without great difficulty. Only when sanitary supervision breaks down as a result of such major calamities as war, may new invasions come about, as was well shown in some of the belligerent countries involved in the catastrophe of 1914–1918.

The prophylaxis of pleuropneumonia may be attempted by (1) immunization and (2) sanitary police measures. The nature of the

outbreak, the number of animals involved and the means at the disposal of the countries concerned usually determine the methods upon which dependence must be placed.

Immunization.—Parallel to the variolization once practiced against smallpox by Oriental peoples, the natives of Africa undertook the protection of their cattle against pleuropneumonia, probably long before similar attempts were made elsewhere. At least, it was not until about the earlier decades of the nineteenth century that, no doubt under the influence of the success of Jenner's vaccination, virulent inoculations were proposed as a means of reducing the toll of the disease (Hanszmann, 1819; Hertwig, 1827).

There is, however, no evidence to indicate that inoculation was commonly practiced in the cattle-growing regions of Europe before 1850, when Willems, a Belgian physician, investigated its possibilities. The results which he published in 1852 demonstrated that the exudate obtainable from the pulmonary lesions contained the specific virus, and that its introduction into the dense subcutaneous connective tissue near the tip of the tail commonly gave rise to a more or less benign reaction followed by a state of immunity which enabled animals to support, without inconvenience, the otherwise fatal intrathoracic injections as well as the exposure to the natural contagion.

After Willems's initial investigations his method of inducing immunity was widely adopted, and although modified and largely supplanted by other procedures it has as yet not been entirely abandoned. The practice was accompanied by certain risks, but in spite of these, and its crudeness, it enjoyed a large measure of success. It certainly reduced the losses caused by the disease, and this alone was widely accepted as an outstanding advance and as a marked improvement over the methods employed prior to Willems's discovery.

The virus used for the inoculation is procured from animals in the earlier stages of the disease. For this purpose the animal is killed and properly bled. With the necessary precautions with regard to cleanliness, the lungs are removed and incisions made into the infiltrated interlobular tissues from which the lymph is carefully drained and aseptically collected. The pleural exudate is also collected. If the liquids thus secured are bright, clear and aseptic, they are deemed suitable for use; cloudy and hemorrhagic materials are rejected.

As a rule, the lymph clots after its removal and must be strained through cloth prior to being stored in sterile containers kept in a cool place. In case the lymph is not immediately needed, about 12.5

per cent of pure glycerin is added, but even so, it should not be kept in storage for more than 2 weeks.

The method of preservation, as well as the time limits for use, vary somewhat in accordance with the experience of the operators engaged in the work. Instead of the glycerin alone, the addition of ½ volume of a 0.5 per cent solution of phenol and ½ volume of glycerin to 1 volume of lymph has been proposed. This mixture is filtered through paper and stored in stoppered bottles, kept in a cool place. This mixture is said to retain its virulence for 2 or 3 months.

The principal disadvantage associated with this method of obtaining virus from natural cases consists in the difficulty of having an adequate supply readily available when most urgently needed. An improvement over this source of inoculation virus was proposed by Pasteur, who suggested collecting the lymph from calves which had been inoculated in the dewlap and shoulder. The edematous swelling which developed as a result of the inoculation furnished a lymph equally as suitable as that obtained from natural cases. It can always be prepared well in advance of a possible demand. This method was first employed in Australia, where it is still used.

The virus obtained by either mode of procedure is inserted into the thickness of the skin or into the subcutaneous connective tissues by means of an inoculation needle, provided with a shallow depression near its point. As the site of inoculation, the tail, at a short distance from its tip, is selected. Two or three punctures about ⅘ inch apart are made, the needle being recharged each time.

As the first result of the inoculation there develops, within 1 to 4 weeks, in about 90 per cent of the animals treated, a hot, hard and tender swelling at the point where the virus was introduced. This is usually accompanied by a febrile reaction. In the more successful inoculations, the local as well as the constitutional reactions disappear in 7 to 15 days; as a less favorable result the swelling becomes extended, shows a tendency toward gangrene and may eventually involve the entire tail, the region of its root and the perirectal tissues.

Such untoward consequences may be due to an unusually high degree of virulence of the lymph inserted or to accidental secondary infection by pyogenic and other pathogenic microbes.

Vaccination losses by death do occur and are variously estimated at from less than 1 per cent to more than 3 per cent of the animals treated, and in a variable proportion of the cases amputation of the

tail becomes necessary. This is a decided disadvantage for animals occupying a fly-infested region.

The inoculation with natural lymph, no doubt, induces, in a substantial number of the animals treated, an immunity regarded to endure for about a year. The protection thus conferred is, however, not an absolute one, inasmuch as a certain number (1 or 2 to 4 per cent) of the animals concerned, may sicken in spite of it or are apt to become virus carriers and spreaders.

Since it has become possible to cultivate the virus in artificial media, the use of cultures for inoculation purposes has been adopted in several countries. The protection it imparts is equal to that obtained by means of the natural virus, and it is claimed to endure for not less than 2 years. Culture virus is less liable to cause post-vaccination complications, and it can be kept more readily available and at less cost.

On the whole, it appears that the culture virus is safer than the natural lymph, although this safety is not an absolute one. In either case, unexplainable failures are apt to be experienced, and the results of any inoculation cannot be predicted with any degree of accuracy.

According to Knowles, the elements of safety associated with the use of culture virus depend on the possibility of producing it without any extraneous contamination. Its virulence can be sufficiently attenuated to safeguard its use. Its antigenic properties are retained, and there appears to be no definite relation between the former and virulence. This author states that strains of virus attenuated by prolonged subculturing may confer a substantial immunity without causing local or thermic reactions.

A first inoculation is made near the tip of the tail and a subsequent one, 3 weeks later, behind the shoulder. According to Knowles, a single dose of 2 c.c. of culture virus, subcutaneously administered, is followed by a strong immunity against an inoculation with virulent lymph.

The various modifications of protective inoculation, such as by drenching with lymph or by the use of virulent setons, are less safe or effective than the ones described above and have, by now, been generally abandoned.

Protective inoculation is useful in the prevention of losses in areas where the more radical measures of prophylaxis cannot be effectively applied. In situations where complete eradication can be contemplated, the inoculations are more apt to retard than to promote the consummation of final suppression.

In countries prepared to deal with the peripneumonia problem in a radical measure, often the most economical of all methods, sanitary police measures, have supplanted inoculation, which at this time plays only a subordinate part.

Sanitary Police Measures.—A considerable volume of experience acquired in various parts of the world is warrant for the opinion that, wherever it is at all practicable, eradication by means of the destruction of all animals affected with peripneumonia, or exposed to it, or even suspected of having been in contact with infected animals, constitutes the most effective and at the same time the least costly method of dealing with the disorder.

However, there always are situations in which such a plan cannot possibly be carried out and where, as the only alternative, inoculation must be resorted to in order to reduce losses. The latter procedure, after all, is only a makeshift measure, which merely prolongs the struggle as well as the obstructions to the cattle trade associated with the quarantine measures by which, of necessity, it must be supported.

In countries where peripneumonia has not too extensively involved the bovine population, where funds can be made available to reimburse owners for animals confiscated and where an efficient livestock sanitary organization can be mobilized against the disease, the more radical method by slaughter must be preferred.

With the application of more accurate and prompt means of diagnosis by serologic tests it may be possible to make such radical measures less costly and to assure earlier results, but even without such an advantage the adoption of radical suppression is fully warranted wherever it is at all possible.

In the United States, where the disease was temporized with for several decades, no material headway was made until it became possible by the establishment of the National Bureau of Animal Industry (1884) under the leadership of Salmon to proceed in a more thorough manner. From the very first, the clear-visioned Salmon warned and pleaded against the use of inoculations, and had to struggle for some years against the views of a vaccine-minded cattle-growing public. By 1889 the inoculations could be prohibited, and from then on a more substantial progress could be made, which terminated in final eradication in 1892.

In areas where complete eradication by the destruction of all affected and exposed animals is contemplated, the infected districts must be isolated by quarantine measures and all cattle movements

from them strictly suspended. The cattle of the surrounding territory should be kept under surveillance. Within the quarantined areas all affected or exposed animals are slaughtered, and their owners adequately compensated for their losses. All other herds in such districts should be challenged by frequent inspection, including serologic tests, frequently repeated.

The elimination of infected and exposed animals and the supervision of the others should be continued until the infection has been completely eradicated. Its consummation can be accepted when: first, an entire herd has succumbed, been destroyed or removed; second, when in a given herd the disease or suspected animals have been eliminated; and third, when among the susceptible or suspected animals, no new cases have appeared during a period of not less than 6 months after the last case or possible contact. The freedom of infection may be further challenged by serologic methods.

The practice of inoculation should be prohibited wherever the slaughter method is depended on for eradication. A thorough terminal disinfection of the premises involved should follow the elimination of the infected animals, and such premises should not be reoccupied by cattle for a considerable period.

In countries where the radical procedure outlined above cannot find application, quarantine measures, including a careful and constant surveillance, must, nevertheless, be enforced. In the Australian states, for example, a quarantine is immediately imposed on the cattle as soon as the disease is discovered. The minimum period of quarantine in the case of an outbreak is fixed at 60 days from the date of the last death or successful inoculation, whichever happens to be the latest.

In one of the Australian states, a period of observation is extended beyond that of quarantine, and cattle are designated as "technically infected" for a period of 12 months after contact with diseased animals and remain under surveillance for that length of time.

Such measures are apparently dictated by local circumstances, but there also it is recognized by livestock sanitarians that more radical measures would bring more satisfactory results. As Henry fittingly remarks, "Under Australian conditions satisfactory control is impossible unless steps are taken to prevent any animal from recovering from pleuropneumonia."

States or countries adjacent to infected territory or in commercial contact therewith must exercise a rigid supervision over their cattle importations. Preferably, only shipments destined for imme-

diate slaughter should be admitted; animals imported for other purposes should be kept in quarantined enclosures until their freedom from infection can be established by prolonged observation or by a repeated application of serologic tests. In most cases, however, the complete suspension of importations should be preferred.

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CHAPTER XXXV

EQUINE INFLUENZA

EQUINE influenza, also designated as influenza catarrhalis, is an acute, febrile, contagious disease characterized by a catarrhal inflammation of the mucosa and not infrequently accompanied by involvement of tendon sheaths and the subcutis.

The disorder has been known since the four and fifth centuries and has often attracted attention by its marked morbidity rate, its rapid spread and wide distribution. The infection tends to linger in centers of equine population in a somewhat inconspicuous manner, to flourish suddenly into an epizootic of great magnitude which is apt to affect a whole continent in a surprisingly brief space of time. Such outbreaks occurred in Europe in 1881–1883 and in this country in 1872–1873 and again in 1900–1901.

Influenza is not attended by a conspicuous mortality rate, but nevertheless the disease is of great economic importance because of the great numbers of horses affected at one and the same time and of the temporary disability of the animals concerned.

As a rule, the disorder is benign in character and runs its course within a week or 10 days or even in less time. In spite of a very marked initial depression of the affected animals, the mortality, as a general rule, remains low, ranging between 0.5 and 4 per cent. Death may follow such complications as gastro-enteritis, nephritis, pneumonia, cerebral disturbances and cardiac failure. Founder and obstinate tendovaginites may prolong the period of illness.

Susceptible Species.—Equine influenza catarrhalis affects only the equidae. Horses furnish the great majority of the cases, but asses and mules are by no means exempt. It has not been possible to transmit the disease to other animal species.

The Virus of Influenza Catarrhalis.—Of the virus of equine influenza no more is known than that it is filterable and ultramicroscopic. It is constantly present in the blood of affected horses and tends to linger there for relatively extended periods after recovery from the disease. In one observation the blood of an artificially infected horse remained virulent for not less than 3½ months.

Vechiu showed that the virus exists in the pleural fluid of the sick animals. Its virus is present also in the saliva of the affected horses and maintains itself in the salivary glands for at least 8 months after recovery from the disease. It has been found in the glandular cysts of the buccal mucosa of animals which previously had the disease.

According to certain authors, the virus may be present in the excretions of affected horses. Its presence could not be demonstrated, however, in the intestinal contents of such animals. It is apparently present in such secretions as tears and mucus.

The etiologic factor of influenza may persist for a great length of time in certain parts of the body. It tends to do so particularly in the seminal vesicles and the prostate gland. In one case the semen of a stallion was still virulent 4 years after the animal had recovered from the malady. All such animals are potentially dangerous, and their presence may explain the occurrence of unexpected outbreaks.

The existence of the virus outside of the animal body is apparently a precarious one, and stables which were occupied by affected horses, as a rule, soon cease to be infective. Virulent blood retained its pathogenic qualities for a number of months when kept in a refrigerator, but when it was stored at room temperature for 6 months the virus had become inactive. The virulence of the blood, kept in this manner, however, was shown to be still intact after a month of storage and caused the disease in typical form in experimental horses inoculated with it.

Modes and Vehicles of Infection.—There is an abundance of evidence which shows the marked infectiveness of horses afflicted with influenza catarrhalis even if exact information regarding the mode of transmission is still lacking. Convalescent horses and even some of those which recovered from the disease are likewise capable of communicating the infection to susceptible animals. Virus-carrying stallions may convey the disease during copulation and have been proved to do so for years. On the other hand, susceptible horses otherwise in contact with such stallions do not contract the disorder.

Influenza can be transmitted to healthy horses by means of subcutaneous and intravenous injections of the body-warm blood of affected ones.

Direct contact is probably the most common means of transmission. Various secretions and excretions are assumed to serve as the vehicles for the virus. Such substances are always apt to be contaminated, if only for a brief period. In the same manner may food and

drink come to constitute a means by which the etiologic factor is conveyed to other animals.

The lymphoid structures of the pharynx probably serve as the port of entrance for the virus and from there it is conveyed to the general circulation. The period of incubation ranges between 2 and 7 days after exposure or artificial infection.

In the general dissemination of equine influenza, contact with diseased, convalescent or recently recovered cases plays a major part. Public stables, markets, stock yards, and other places where considerable numbers of horses are assembled, serve as clearing houses of infection, and there can be no doubt that the commerce and traffic in horse stock is fundamental to the whirlwind distribution of the disease.

Factors Favoring Infection.—Only one condition can influence susceptibility to influenza catarrhalis, and that is recovery from the disease. This susceptibility is not modified by age, breed, season or the régime of feeding or management. Recovery from the disorder, in the great majority of cases, is followed by an enduring immunity, even if the repetition of the disease has been recorded in a number of instances.

The spread of the infection in an equine population, on the other hand, is materially influenced by the movement of horses. Nothing promotes the spread of influenza catarrhalis more than a lively traffic in horses.

Prophylaxis.—Owing to the highly contagious character of influenza, attempts at prevention are commonly attended by failure; this is especially the case in the course of widespread epizootics which are apt to involve the equine population of extensive areas. During the periods when the influenza incidence is low, caution in the management and movements of horses will, in a measure, tend to protect disease-free stables.

Measures of preventive value include the avoiding of public stables and the isolation of recently purchased horses. The animals thus segregated should be subjected to temperature measurements, and if, at the termination of a period of 7 to 12 days, no febrile reaction could be recorded, it would be relatively safe, so far as influenza is concerned, to bring them in contact with other horses.

During the prevalence of equine influenza the timely segregation of the first case may be a means of protection. Without regular temperature measurements, however, it may be difficult to do so with the necessary promptness. Stalls thus vacated must, of course, be thoroughly disinfected.

Once the disease is established, perhaps the most suitable procedure is to expose all the healthy horses to the affected ones, by placing them in intimate contact. Animals so exposed should be kept at rest until they have completely recovered. This method, which is prescribed in German military organizations, is followed by a rapid sickening of all horses, which materially shortens the outbreak and leaves the animals more or less permanently immune to subsequent infection.

Artificial infection by the inoculation of virulent blood, or other material, has been attempted, but on the whole the disease resulting from such a procedure was less benign than the one which ordinarily follows exposure by natural contact alone.

The many efforts to immunize horses in various ways have not been followed by satisfactory results.

Stallions which recovered from influenza must be looked upon with suspicion and should be withdrawn from service unless by trial matings with susceptible mares it could be proved that they had not become virus carriers.

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CHAPTER XXXVI

INFECTIOUS PLEUROPNEUMONIA OF THE HORSE

EQUINE infectious pleuropneumonia is an acute, specific, febrile, communicable disease characterized by croupous pneumonia and pleuropneumonia which is more or less frequently complicated by involvement of the cardiac and renal parenchyma, tendovaginites and serous infiltrations of the subcutis. In German veterinary literature the disorder is commonly designated as "Brustseuche."

The disease commonly occurs wherever large numbers of horses are assembled, such as in military remount establishments, horse markets, dealer's stables, etc. In such places infectious pleuropneumonia often exists enzootically. This is especially the case in the large horse markets of this country, where there is a constant movement of horses belonging to the most susceptible age group.

In such centers, horse stock directly from farms is received, assembled and, after a brief sojourn, passed on to ultimate buyers. There the infection is constantly maintained by the influx of new stock, which is thus exposed to direct-contact infection.

Such animals, often subjected to the hardships of long journeys by rail, arrive at their destination either with the disorder already established or with its period of incubation well advanced. These circumstances are responsible for the term "shipping fever," "acclimating fever" or "western horse fever," by which the disease is best known among horse dealers and buyers.

The malady manifests itself by an initial febrile period, soon to be followed by pulmonary involvement, as well as by the other morbid conditions already enumerated. In its more severe forms gastrointestinal complications are apt to develop as well as cardiac impairment, meningitis, nephritis, pyemia and septic intoxication. In a certain number of the cases recovery is only partial, as pulmonary sequestra and pleuritic adhesions tend to bring about a permanent respiratory complication with or without constitutional depreciation.

The progress of infection of pleuropneumonia in a stable of susceptible horses is commonly slow and insidious after the initial intro-

duction of the specific virus. One case, less frequently two or more, declares itself, and no others may be discovered for two or three weeks. At the expiration of this period, new cases are recognized in increasing numbers until an outbreak of an epizootic character is thoroughly established.

The mortality rate of equine infectious pleuropneumonia shows a wide range of variations. It usually fluctuates between 1 and 20 per cent in accordance with the conditions to which the animals were exposed, the management of the outbreaks and the clinical care bestowed upon the affected animals. Mortality has been greatly reduced since the introduction of the salvarsan treatment.

The economic damage inflicted by the disease is not entirely due to losses by death; the permanent physical depreciation which follows in a number of the cases must also be reckoned with.

Susceptible Species.—Infectious pleuropneumonia is a specific disorder of the horse; there is no evidence to show that the transmission of the disease has ever occurred in other animal species. It is apt to affect all breeds of horses, and although its transmission to other solipeds is admitted by a number of authors, it is quite apparent that their susceptibility is only a slight one when compared with that of the horse.

In the veterinary practice of the author in a locality where the equine population consisted of approximately an equal number of mules and horses, infectious pneumonia was exceedingly common among the latter. Yet cases in mules were so rare that even now he is in doubt of ever having observed the disease among these animals. In his clientele among large commercial and industrial establishments, mules greatly displaced horses for no other reason than to avoid the losses and inconvenience occasioned by "Brustseuche" among the latter.

The Virus of Equine Infectious Pleuropneumonia. As yet no definite knowledge regarding the virus of equine pleuropneumonia has been acquired. The experiments by Gaffky and Lührs warrant the opinion that it is to be found in the epithelia of the air capillaries and alveoli of the lungs. The presence of certain cell inclusions may indicate that the etiologic factor of the disease is parasitic in nature. There is evidence which strongly indicates that the virus remains localized in the pulmonary epithelium and that it does not disseminate throughout the body and its organs. Apparently the virus does not maintain itself in a viable state for extended periods outside the animal body.

There is no good evidence to prove that the various microbic species, from time to time proposed as the actual cause of the disease, have any primary etiologic relation to the latter. As secondary factors, however, they may play an important part in connection with the clinical and pathologic aspect of the disorder. Among these the various strains of Streptococci appear to be most conspicuous.

Modes and Vehicles of Infection.—Horses actually affected with infectious pleuropneumonia are the predominant source of infection. Such animals remain infected throughout the entire course of the disease, including the period of convalescence. The part played in transmission by apparently healthy virus carriers must also be given consideration.

In the majority of the cases the transmission of the infection is the result of direct contact. The part played by intermediary carriers may be admitted, but apparently this is not a common mode of transmission. It is quite probable that the common watering trough, frequented at short intervals by affected and healthy horses, serves as a potent vehicle for the virus.

Although the entrance of the virus through the alimentary tract cannot be positively excluded, there is agreement among observers that in most cases the infection finds entrance by way of the upper air passages. Artificial infection does not always result in the transmission of the disorder, although it was found to be possible to convey the virus by the introduction of the bronchial secretions of a recently affected colt into the nose and mouth of a healthy one, with the development of actual disease as a result. Even in the case of the most intimate contact, positive infection appears to be subject to the presence of certain conditions of which the nature is as yet unknown.

The incubation period is subject to considerable variations in length. It ranges between a few days and 3 to 6 weeks.

Factors Favoring Infection.—Age exercises a certain influence on the morbidity rate of equine infectious pleuropneumonia. The age group of 5 to 10 years supplies most of the cases, although younger animals are by no means exempt. The reduction of morbidity shown by the older groups is largely to be attributed to immunity engendered by the disease earlier in life. As a rule, recovery is followed by a substantial resistance to subsequent exposure. This immunity usually persists during the lifetime of the animal, although subsequent infection is not entirely unknown.

Certain environmental factors tend to promote infection. Chilly, damp weather and ill-ventilated stables render horses more liable to infection, and over-work, under-feeding, pre-existing catarrhal affections of the respiratory tract and especially the hardships incidental to a prolonged railway journey not only increase susceptibility, but often exercise a pernicious influence on the course of the disease. No other factor increases the mortality rate more than the practice of horse owners and dealers of putting horses to work which already show the initial rise of temperature characteristic of the disease before other clinical evidence of disturbance can as yet be observed.

Prophylaxis.—In view of an apparent futility of sanitary police measures which can be directed against equine infectious pleuropneumonia and in the absence of a dependable method of immunization, the prevention of the disease must be largely confined to efforts to reduce the hazard of virus introduction and of its spread in a given stable or establishment.

When infection hazard is known to exist, all horses should be subjected to daily temperature measurements. Under such circumstances, any horse showing a rise of temperature should be promptly segregated and its stall and harness adequately disinfected. This measure has the further advantage of bringing to light incipient disease in animals which otherwise would have been keep at their usual work. The suspension of work before pulmonary involvement declares itself is a most potent factor in the reduction of mortality.

If season and weather permit, the segregated animal should be kept at pasture or in a paddock, and advantage should be taken of such an opportunity.

Horses acquired from regular dealers or those originated from other suspected stables should not be introduced in those occupied by susceptible ones. They should be isolated for the purpose of observation for periods from 3 to 6 weeks. The longer period, no doubt, assures a maximum of safety.

Convalescent horses should always be regarded with suspicion and should not be admitted among a lot of susceptible ones for at least 6 weeks after the completion of recovery.

These measures must be supplemented by a thorough cleaning and disinfection of the stable and the adequate disposal of all manure, food, remnants and other rubbish. In the presence of the disease, the common watering trough should be discontinued and individual pails provided.

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CHAPTER XXXVII

FOOT AND MOUTH DISEASE

Foot and mouth disease or aphthous fever is an acute, very contagious disease of artiodactylous animals, which manifests itself especially by a vesicular eruption of the mucous membrane of the mouth, of the skin of the intradigital spaces and of other parts. It is not certain how long the disease has been recognized as a distinct entity, but there is historical evidence that it has been observed in its present clinical form for more than 400 years.

Its capacity for rapid and far-flung dissemination and the several species of livestock susceptible to it combine to give aphthous fever the qualities of a formidable scourge damaging to the producer of livestock, disturbing to commerce and baffling to the sanitarian.

The relatively low mortality rate (1 to 3 per cent) commonly marks the disease by a rather benign character, although occasionally it shows a maligant tendency responsible for heavy losses by death.

Its capacity for damage is more particularly associated with its high morbidity rate among an exposed population of susceptible livestock as well as with the sequelae which are apt to follow in its wake. There always is a marked reduction in flesh of the affected animals and a severe falling off in milk yield; abortions, incapacity for work (oxen), unduly prolonged periods of convalescence and serious impairment by secondary infections augment the damage inflicted.

The average direct loss sustained in outbreaks is never less than 10 per cent of the commercial value of the animals concerned, and instances in which this loss amounts to 20 or 30 per cent are not rare. To this must be added the more indirect losses occasioned by the interruption of such trades as dairying and livestock marketing, and the commerce in by-products of animal origin and of farm products in general is bound to suffer by the necessary quarantine restrictions.

Host Species.—The susceptibility of domesticated animals to foot and mouth disease pertains particularly to cattle, swine and sheep, which supply the preponderating number of cases. Of these, cattle and swine are the most susceptible; sheep and goats are relatively

more resistant. Buffaloes, camels, reindeer, llamas are also susceptible, and the wild artiodactyls, such as deer, antelope, chamois, bison, giraffe and others, are also liable to the infection. Elephants are reported as having shown a degree of susceptibility.

The horse, dog and cat may, on rare occasions, contract the disease by natural exposure, although these animals are always quite resistant to artificial infection, with the possible exception of young dogs. The disease is rarely seen in poultry, but birds in general cannot be regarded as being susceptible; attempts to inoculate in various ways a series of 32 fowls, 2 ducks, 10 martins and 6 sparrows were followed by negative results.

Aphthous fever is transmissible to man (milk-borne infections), and fatal human cases have been recorded.

Rabbits, and white as well as wild rats show varying degrees of susceptibility after artificial inoculation, although natural infection during captivity certainly appears to be very rare even if this does not permit the exclusion of the possibility of aphthous infection among these animals.

The guinea-pig is susceptible to artificial inoculation and has proved to be a valuable experimental animal. However, this animal does not become infected with the disease when kept in close contact with affected cattle.

The Virus of Foot and Mouth Disease.—The causative agent of foot and mouth disease is an ultramicroscopic organism capable of passing through the Chamberland and Berkefeld filters though it is at least partially retained by filters of greater density. The stable characteristics of the pathologic processes to which it gives rise in the susceptible species have always been regarded as warrant for the belief that the virus is a specific biologic entity, but the more recent demonstration of at least three strains which do not appear to have any immunological relations *inter se* challenges this old opinion.

The virus is always present in the fluid contents of the vesicles of the skin and the mucosa, and it is especially apt to endure in the epithelial coverings of the aphthae.

In the earlier, febrile, pre-eruption stage of the disease, the virus is also contained in the blood. It may be found in the milk even before the eruption of the visible vesicles during the initial febrile period.

Various secretions, notably the saliva, are usually virulent, and this seems to depend principally on the admixture of the fluid which escapes from the vesicles after their rupture. Contained in the fresh

vesicles, the virus is endowed with its maximum virulence. This tends to decline, however, and it was shown that the saliva of affected animals was no longer virulent 10 days after they had manifested the first symptoms of the disease.

Although most constantly present in the affected animals, the virus of aphthous fever is commonly present in and on many objects belonging to their environment, a circumstance which plays an important part in the spread of the infection.

The power of the virus to resist the influence of adverse external factors has been commonly underestimated, and in the older literature especially, its capacity for enduring in various situations outside the animal body is often represented as being rather transitory in character. With the accumulation of more knowledge of the subject, it became quite apparent that the virus might retain its viability and virulence for considerable periods and that it would be a mistake to place dependence on a marked vulnerability of the virus when sanitary regulations are to be formulated.

The variance of the observations recorded must be attributed to many contributory factors, which, although not apparent, may, nevertheless, exercise a potent influence on the fate of the virus.

In most of the media in which the virus of foot and mouth disease is apt to occur, it will survive for a period lasting from 5 to 11 days. In one observation it was found to be active during the latter period when mixed with sand and stable filth, but on another occasion it remained alive in open stable drains for at least 40 days.

When kept in sealed capillary tubes the virus was still active after 2 weeks and the virulence had not entirely disappeared after a period of 8 or 9 weeks.

The blood of infected animals kept at temperatures of 0 to 2° C. retained its virulence for varying periods but probably not longer than 3 months, and the virus remained alive while contained in artificial media at room temperature for more than 69 days, but not beyond 100 days.

Virulent material placed in the soil was still active after 25 days, and the coverings of vesicles stored in a sack filled with hay retained their virulence for 30 days, but after a storage of 50 days it had disappeared.

The alternate action of freezing and thawing failed to destroy the virus within 124 days.

The virus is quite resistant to the effects of drying, especially if this be done with rapidity. The vesicular fluid dried on glass plates

in vacuum maintained its virulent character for 18 days, and when under similar circumstances it was dried over sodium hydrate the virus was still intact after 100 days. That contributory factors play an important part is shown by the observation that a virus dried on glass plates, kept in a dry atmosphere over sulphuric acid at a temperature of 18° C., survived for from 4 to 12 months, whereas the same virus treated in a similar manner, except that a relative humidity of 50 to 70 per cent was maintained, showed a maximum surviving period of only 5 days.

Dried on cow's hair, sand and salted butter, the virus remained active for periods of from 2 to 4 weeks, if kept at temperatures ranging between 56 and 60° F. and with a prevailing relative humidity of 52 per cent.

Flies moistened with the contents of vesicles remained infected for only 2 days, and the virus dried on linen survived for 5 days. Dried on bran and hay, the virulence was retained for periods ranging between 8 and 20 weeks.

Exposure to direct or diffused sunlight shortens the period of survival of the virus, and wood, stone, flannel or similar materials on which the virus has been dried are rendered sterile in 24 hours, by such an action.

The virus contained in the coverings of the vesicles is most resistant to external influences; even if subjected to the action of sunlight, warmth, putrefaction and desiccation, it may retain its virulence for several weeks.

When contaminated substances, such as grass and hay, were continuously exposed to light which had passed through window glass, the survival of the virus was considerably shortened.

The virus of aphthous fever is most sensitive to the action of heat, and generally, when kept *in vitro* at 34° C., it does not survive for more than 1 week. Kept at 37° C., it dies within 24 to 48 hours. Heated to 50° C., it succumbs after 15 minutes; to 60° C., after 5 minutes; to 80° C., at once, although there may be differences in heat resistance determined by the character of the medium in which the virus is contained.

The chances for survival of the virus are reduced in the presence of putrefaction, although temperature and moisture may tend to modify this influence. Contained in well-packed manure at a depth of 8 inches, the virulence disappears after a storage of 8 days; in another observation, the virus stored at a depth of 1 foot was surely killed within 6 days.

The virus contained in milk appears to be vulnerable to the action of the acid developed during the souring process.

The resistance of the virus to the action of chemicals and disinfectants also appears to be more marked than it was once considered to be. Glycerin preserves the virus, and it was shown that whereas a virus contained in sealed tubes retained its virulence for 190 days, it was still virulent after 204 days when it was mixed with a 50 per cent glycerin-saline solution, and that the preserving power of the glycerin was even more marked if, for the saline solution, a $N/25$ phosphate solution was substituted.

Although the vulnerability to antiseptics of the virus of aphthous fever is often attested to (1 per cent phenol, 2 per cent formalin, 3 per cent soda, 1 per cent hydrochloric acid, within 1 hour), it is significant for practical purposes that, under experimental conditions, the virus was found to be still active after a contact of 6 hours with a 0.1 per cent sublimate solution and a 3 per cent cresol solution. Still more striking was the observation that a 25 to 50 per cent alcohol does not destroy the virus during a 3-day exposure, and that it is quite resistant to the action of chloroform and ether.

Apparently the disinfectants which cause coagulation are least efficient. It was found that a 1 to 2 per cent sodium hydrate solution which causes no coagulation destroys the virus in 1 minute even if it was contained in urine, feces or soil. Evidence is further presented which tends to show that the virus is particularly vulnerable to an aqueous solution of sulphurous acid (5 per cent).

Modes and Vehicles of Infection.—One of the more pronounced characteristics of aphthous fever is its ready transmission by direct and indirect contact. The virus is extremely active and is capable of causing positive infection even when highly diluted. In dilutions of 1: 10,000,000 the virus, in several instances, was found to be still active, and the disease can be transmitted with quantities of virus ranging from 1/5000 to 1/20,000 of a cubic centimeter.

The principal source of the virus is the fluid escaping from the ruptured vesicles, but the coverings of the latter also play an important part. At least, there is evidence which tends to show that the epithelial coverings contain the virus in a concentrated form and that the latter in the situation mentioned is especially resistant to external influences. It seems that the virus permeates the epithelial cells as the repeated washing of the cells fails to deprive them of their virulence.

The virus escapes from the body when mixed with secretions and

discharges. The saliva is particularly active as a vehicle, and as the severe irritation of the mouth stimulates its secretion it plays a major part in the transmission of the disease. The masticatory movements of the jaws permit its ready escape, and as this discharge commonly takes the form of a light froth a small quantity is sufficient to contaminate a considerable portion of a stable or other surroundings.

By droplets of discharge suspended in the air or by wind-borne froth, both the atmosphere of a stable or of the out-of-doors may become a factor in the distribution of the infection. These are, however, the only known circumstances under which the virus may be carried by the air.

All the other secretions, excretions and body wastes are apt to contain the virus and must be regarded as possible vehicles of infection. After the saliva, the milk of affected animals is particularly apt to convey the infection. Not only may sucking calves contract the disease in that manner, but the by-products of creameries and cheese factories, distributed for livestock feeding, may cause such industrial establishments to become real clearing stations of infection.

In one outbreak occurring in the United States, the disease had its origin among some calves used for the propagation of vaccine virus, which, in all probability, was introduced into the country from foreign parts where aphthous fever was prevalent.

Hog-cholera antiserum and virus used in the control of that disease may also become the means of disseminating foot and mouth disease if these substances were obtained from infected swine.

The blood may serve as a vehicle for the virus during the earlier phases of the disease and on occasions may have to be reckoned with as such even if its virulence may be feeble and difficult to demonstrate.

Susceptible animals in close propinquity with affected ones are certain to contract the disease by direct contact, although indirect contact is probably fully as frequent a means of transmission.

An innumerable assortment of objects is prone to become contaminated in the immediate or even more remote environment of affected animals. Food and water, pails, troughs and all that goes to make up a stable equipment may thus serve as infection vehicles. Persons may become intermediary carriers through the contamination of their garments, and the hair coat and feet of all animals, (including dogs, cats, poultry, etc.) may in a similar manner become agents of transmission. Consideration must also be given to flies, rats, sparrows and other birds.

Even though affected animals usually cease to be sources of infec-

tion after the completion of convalescence, the possibility of a prolonged carrying of virus cannot be neglected. Such virus carriers are probably uncommon, but that they must be reckoned with is shown by the fact that it was found to be possible to transmit the disease to cattle by means of the trimmings of the hoof horn of animals which had recovered from aphthous fever more than 8 months before. It is assumed that, during the course of the disease, vesicles developed on the true derma of the claws, and that the adjacent hoof horn absorbed their virulent contents.

A more temporary carrying of virus may be associated with that which had become dried on the hair coat and especially on parts soiled with the dung. The transmission of the disease from stable to stable in a given area comes about by intermediary carriers such as persons; articles of commerce like hay, straw and feeds may also play a part.

Stock yards, markets, auctions are common and frequent means by which the dissemination of the infection comes about, and public pastures and even the highways used by infected livestock have apparently served to bring similar results. The channels of commerce are especially apt to be followed by the disease which in this manner may become transported over long distances.

Artificial infection is possible by intravenous, intracutaneous, intramuscular or intraperitoneal inoculation, by rubbing the virus into the skin or mucous membranes and by dropping it into the conjunctival sack, as well as by ingestion. In the majority of the cases the alimentary tract is the more common port of entrance for the infection.

The introduction of the virus is followed by an incubation period of from 2 to 7 days, and the introduction of an affected subject into a healthy herd is usually followed by the initiation of the outbreak within 6 or 10 days after the contact was made.

The length of the incubation period is influenced by the volume of virus introduced as well as by the animal species involved. In cattle the average length of this period is from 2 to 7 days (minimum 24 to 28 hours, maximum 7 to 14 days). It is shortest in swine (24 to 48 hours), and the average length for sheep is from 1 to 6 days.

Factors Favoring Infection.—Aphthous fever once introduced among a population of susceptible animals does not appear to be materially influenced by factors which either promote or retard the pathogenic functions of its virus. Exposure means infection of old and young alike, although the very young and the more feeble adults

probably suffer most of its effects and are more seriously damaged than the more vigorous individuals.

The progress of an epizootic may, however, be influenced by various factors not all of which are precisely known. A seasonal influence is commonly apparent. During the warmer season the dissemination of the disease progresses more rapidly; the epizootic is apt to show its greatest incidence in late autumn, but declines during the cold weather.

It is, however, quite possible that the influence of season *per se* is more apparent than real, and that the behavior of the disease is somewhat determined by the distribution of the livestock during the periods mentioned. The facilities for spread are, no doubt, greater when the animals are at pasture than when they are divided in the more compact, isolated groups peculiar to the stabling season. A lively trade in livestock and heavy movements of the latter always tend to promote the extension of the disease.

Differences in susceptibility determined by race and breed are, however, to be noted. The strains of cattle peculiar to regions where the disease has for long periods maintained itself in an enzootic manner are prone to be more resistant than the animals inhabiting areas which are invaded after more or less extended intermissions. The bovine population of central and western Europe is liable to have to sustain a morbidity of 95 to 100 per cent, while the gray cattle of the steppes of eastern Europe and Asia may show the relative low morbidity of 40 to 50 per cent. The resistance of the latter type of cattle is even apparent when artificial infection is attempted, as from 20 to 30 per cent of these animals may prove themselves to be refractive.

The various observers agree that animals which recovered from the disease have acquired a definite immunity or resistance to a later infection. The duration of this resistance appears to be variable and somewhat instable. There are observations which indicate *that* even 2 or 3 weeks after a manifest recovery the animals sicken again, but on the other hand an immunity lasting up to 2 years has been recorded. In the greater portion of the cases the acquired immunity endures from 6 months to 1 year. It is not impossible that the presence of distinct strains of virus, specific from an immunological point of view, may be a factor in these cases in which animals become subject to a subsequent attack within a short period after the first one.

Epizootological Considerations.—Foot and mouth disease has, from time to time, made its appearance in all parts of the world. In Asia

and probably also in certain regions of northern Africa the disease exists enzootically, and from these permanent infection centers it periodically invades the more susceptible cattle populations of other countries. The disease follows the highways of commerce or merely extends its area of distribution by territorial continuity. Only the Australian and North American continents have thus far escaped the permanent establishment of the disease and that only by sustained vigilance and by energetic and costly measures.

On several occasions the United States was invaded by aphthous fever; outbreaks occurred in 1870, 1880, 1884, 1902, 1908, 1914 and 1924. Australia has been free since 1865, when two infected herds were destroyed in order to safeguard its cattle against the scourge.

Epizootics have occurred on the South American continents, and the disease also made its appearance in Southern Mexico in 1926. It appeared in Jamaica in 1922, and the island sustained a formidable outbreak.

Europe has been periodically invaded by the disease, spreading from the adjacent Asiatic territories in a western direction until central and western Europe were covered in a period ranging between 2 and 4 years.

Formerly such an epizootic would finally exhaust itself and then an intermission of several years would intervene. In modern times, when the disease is more or less successfully opposed by sanitary police efforts, its spread is retarded although more limited outbreaks cannot always be prevented. Whereas formerly the rapid involvement of the entire cattle population caused the disease to exhaust its resources, the control measures of more recent times make it possible for a new generation of susceptible young stock to supply the disease with fresh hosts.

Only countries protected by natural barriers such as Great Britain and Norway have been able to prevent the wide dissemination of the infection throughout their territories, and that at the cost of strenuous and radical measures.

It is doubtful if any part of the Orient is permanently free from the disease. It is prevalent in India, China and the Philippine Islands, and the other parts of Asia and the countries adjacent to the mainland are continuously menaced.

The disease occurs in Northern Africa and the Sudan, but the South African Union appears to be free from infection.

The many infection centers distributed over a large portion of the world, the great infectivity of the disease as well as the intense traffic

in animals and animal products combine to place in jeopardy the livestock in all countries; the most rigid and often radical measures are constantly required to ward off the danger of invasion.

Prophylaxis.—Many factors contribute toward making the prevention of foot and mouth disease one of the most difficult tasks of the livestock sanitarian. The existence of permanent infection centers in the Orient and probably also in other parts of the world, the high degree of infectiveness of the disease, its capacity for rapid spread and the ready inoculability of its virus as well as the latter's capacity for remaining virulent for long periods while detached from the animal body, are factors which commonly render prophylactic efforts ineffective unless they are applied under exceptionally favorable circumstances.

As long as it is not possible to deal radically with the infection reservoirs of the Asiatic continent and other regions, the adjoining territories, and through them, the cattle population of all other parts of the world will be menaced directly or indirectly, but withal in an enduring manner.

To the formidable obstacles which confront the livestock sanitary organization must be added the irksome character of the measures required. These frequently prevent the enlightened and effective cooperation of livestock owners, a factor without which practically all disease control becomes ineffective or entirely impossible.

All difficulties notwithstanding, the enormous interests at stake, as well as the soundness of the repressive measures proposed, are warrant that this formidable scourge should not go unchallenged. In many regions sanitary police measures may have resulted only in a temporary check in the spread of the disease; other efforts may have been entirely fruitless, yet there is evidence to show that the eradication of the infection from an invaded area is not impossible if prompt, energetic and amply sustained action is taken.

In few of the major epizootic diseases is the prophylactic technique more thoroughly determined by local circumstances, by the character and organization of the livestock sanitary service and by the strength of the national wealth than in aphthous fever. In regions isolated or remote from the permanent infection foci, an efficient sanitary organization, with adequate financial support, may successfully eradicate the disease soon after its appearance. It is different in countries always more or less open to invasion from adjacent territories over which they have no control, no matter how well they are organized for sanitary service. If this service is feeble or without public sup-

port the tide of the epizootic cannot be stemmed in a radical manner. In such a case the disease is apt to persist until it has exhausted itself by the totality of morbidity.

Efforts in prophylaxis may be grouped as sanitary police measures, emergency inoculation and immunization.

Sanitary Police Measures.—The only sanitary measures which can reasonably be expected to prevail against foot and mouth disease are those which may be executed by organized states or governments in the exercise of the police power. Hence the success or failure of the efforts made are principally dependent on the nature and organization of a livestock sanitary service, on its vigilance, on the promptness by which action can be taken, on its financial resources and on the intelligent co-operation of the owners of livestock.

The most effective efforts in the prophylaxis of aphthous fever are those which pertain to the sanitary supervision of the importation of livestock and of products of animal origin, and to the handling of the circumscribed initial outbreaks.

Intelligence with regard to the prevailing morbidity in other countries is essential, and that not only in view of possible importations of animals or their products, but also of such materials as hay, straw and other foodstuffs. In accordance with an American experience, even such substances as vaccine virus are to be looked upon with more than a casual suspicion.

Importations of the character mentioned from countries, states or areas in which aphthous fever is enzootic or from which it has been reported must be rigidly forbidden. Animals originating in territory which may be regarded as exposed should either be included in the embargo or should be subjected to a quarantine extending over a period certainly not less than 2 or 3 weeks. In the event of the disease appearing among the quarantined animals, the whole importation should be destroyed and adequately disposed of. No detail of disinfection and destruction of contaminated stables or substances should be omitted.

If, in spite of all such precautionary measures, the disease has made its appearance, eradication by means of the slaughter and adequate disposal of all susceptible animals involved in the outbreak or exposed to the contagion must not be delayed, and a rigid and complete quarantine of the affected area should supplement the measures taken.

To what extent such a radical procedure can be persisted in depends on local circumstances. It has been signally successful in the

United States, which on several occasions prevented diffusion of the disease among its livestock. The policy to be adopted in such initial invasions must be largely governed by the cost of the measures to be executed, the total value of the animal population to be protected and the financial loss which the spread of the disease may inflict. The cost of eradicating the infection centers in the California and Texas outbreaks of 1924-25 amounted to approximately $7,500,000, but the expenditure of this sum safeguarded a population of susceptible animals of an estimated (1924) value of more than $2,880,000,000. The efforts made prevented the entire North American continent from becoming involved in a possibly permanent establishment of infection and thus relieved its animal industry from an incubus which otherwise would have required years to remove at a stupendous price.

In countries adjacent to permanently infected regions, like the states of Europe, where the disease is apt to break out simultaneously in several areas, it is not always possible to continue the struggle by means of slaughter even if it may be successfully attempted in the beginning.

The disease may invade a livestock population with such rapidity and involve such a great number of animals that the slaughter method would prove to be too costly to be further supported. In such instances, the individual outbreak must be dealt with by methods of segregation and other attempts to prevent the extension of the contagion from infected establishments and by the erection of barriers which tend to safeguard the non-infected ones.

The nature of the disease and the circumstances under which it occurs and propagates itself often render the measures taken quite futile. Nevertheless, it seems possible for a well-organized sanitary service to effectively check the spread of the disease. The German epizootic of aphthous fever of 1920-21 was successfully restricted to only 25 per cent of the herds of susceptible livestock.

Among the measures to be taken in epizootics in which the radical slaughter method can either not be undertaken or in which it failed to suppress the disease in the beginning, mention must be made of segregation, quarantine, establishment of zones under special supervision and the restriction of livestock traffic and the movement of persons, as well as the sterilization of milk and the embargo on forage and feeds.

All these efforts must be supplemented by effective terminal disinfection of the premises involved and even of the animals which recovered from the disease. This process of disinfection should include the

trimming of the feet in order to prevent the virus contained in or on the hoof horn from being transported.

For countries such as the United States and Australia, already protected by their remoteness from permanently infected regions, the slaughter method is, without doubt, the most effective and the most economical. In countries similarly situated it would indeed be fatal to temporize with any other measures.

Emergency Inoculation.—Under circumstances when the eradication of foot and mouth disease by the slaughter method cannot be put in practice, or when, in the course of a general epizootic, individual herd outbreaks have to be managed in the most economical manner possible, the practice of emergency inoculation offers a decided advantage.

Instead of permitting the disease to spread through a herd in which it may have appeared in a more or less leisurely manner, the simultaneous exposure of all animals is deliberately brought about. This is apt to shorten the outbreak as a whole, and thus bring about a notable abbreviation of the inescapable inconveniences of quarantine and reduce the economic losses incidental to a more prolonged outbreak.

The method has been accredited to European farmers, who reasoned that, as long as a 100 per cent morbidity in their herds could not be avoided, the more rapidly the animals sickened, the sooner could normal production be resumed. The establishment of sanitary police regulations only emphasized the value of the deliberate exposure which, in the territories involved in an epizootic, offers the additional advantage of shortening the duration of the infection foci.

The procedure is of undoubted value when the plague has to be combated under the circumstances related.

As most commonly practiced, the virulent saliva of the affected animals is transferred to the mouth of the ones still healthy by means of a swab made by wrapping pieces of cloth around the end of a short stick. More refined methods are also used, such as the intravenous injections of small quantities of virulent blood. Waldman proposes to secure the virus from intact vesicles of a few recently affected animals. The coverings of the vesicles are also to be removed and crushed with a small quantity of saline solution. The mucous surfaces of the lips of the animals to be inoculated are then slightly scarified and a drop or two of the virulent mixture gently rubbed in.

The method of emergency inoculation is not altogether free from hazard, as rather maligant cases may occur among the inoculated

animals. It is, however, not always possible to determine definitely that the mode of infection was responsible, because severe cases may also result from natural exposure. Risks arising from the practice of emergency inoculation may be mitigated by the injection of convalescent or hyperimmune serum.

The deliberate inoculation is, of course, permissible only in infected herds or establishments, and during the progress of the outbreak the prescribed segregation or quarantine, or other sanitary measures, must not be relaxed.

Immunization.—Even if the resistance to a subsequent exposure acquired by animals which recovered from aphthous fever may be somewhat instable and evanescent, there can be no doubt that even an immunity valid for a few weeks would be extremely useful in countries particularly exposed to the epizootic invasions of their livestock.

In areas where the radical extirpation of the initial outbreaks cannot find application, any method of immunization would prove to be of value in the prophylaxis of the disease and in checking its spread.

It was pointed out at a relatively early date that the blood, or blood serum, of recently recovered or convalescent cattle, when injected into infected animals, exercised a beneficial influence on the character and course of the disease, and that in healthy ones, so treated, a passive immunity lasting from 2 to 4 weeks may thus be conferred. Later, an attempt was made to improve the potency of the serum by a process of hyperimmunization, during which the immune animal is subjected to repeated inoculations with virulent material. As yet there does not appear to be unanimity of the published opinions regarding the relative potency of the serum of recently recovered animals and that obtained by hyperimmunization.

Although the use of any type of protective serum, as a means of prophylaxis, may not be generally accepted in the countries where the disease is a frequent problem, there is evidence that under certain circumstances it may have a definite place in the general scheme of prevention. Used in combination with artificial infection (emergency inoculation), serum injections appear to be of value, and there is warrant for their application in the case of animals temporarily exposed to a possible contagion. Cattle in transit or those which are concentrated at markets and shows may thus have conferred on them a temporary resistance which renders them less liable to play a part in the dissemination of the disease.

The principal disadvantage associated with the use of the serum is the relatively large amount required to bring about the desired degree of protection. Doses ranging from 200 to 1000 c.c. per animal appear to be necessary for the purpose in the case of bovine animals.

Swine and sheep are more readily protected than cattle, and there are indications that outbreaks among these animals have been aborted by the use of a highly potent serum.

The intensity of the exposure exercises an influence on the success obtainable by the serum injections, the latter being more effective against relatively small amounts of virus. In infected regions where the infection hazard may last for periods of 6 months, or longer, protective treatment cannot be depended on unless the injections are repeated every 2 weeks until all risks have disappeared, a procedure probably too costly for general adoption.

The following procedure has been proposed for recently infected herds. The healthy and diseased animals are determined by the use of the thermometer. The animals having a normal temperature are then subjected to a virulent inoculation (emergency inoculation), and are simultaneously injected with serum (8 to 10 c.c. per 100 kilos body weight) while the affected animals receive a maximum dose of serum (10 c.c. per 100 kilos body weight).

Attempts to secure an active immunity by the inoculation of an attenuated virus have not been generally successful, although favorable results obtained with a formalized virus have been reported.

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CHAPTER XXXVIII

HOG-CHOLERA

Hog-cholera or swine fever is an acute septicemia readily transmissible and characterized by an initial high temperature, by gastro-intestinal disturbances, by loss of appetite and by a very high mortality rate.

So far as its occurrence has been recorded, the disease first came to the attention of swine growers in the United States about a hundred years ago, and during the latter half of the nineteenth century it also made its appearance in England, Sweden, Denmark, France, the Netherlands, Germany, Austria, Hungary and other European countries. It has also been observed in Asia, Africa (Transvaal) and Australia.

In the United States it is the chief source of losses among swine; wherever a dense hog population is maintained it constitutes a hazard to be reckoned with. With a mortality rate ranging between 70 and 100 per cent of the exposed susceptibile animals and a marked degree of contagiousness, it ranks high among the major scourges of domesticated animals.

The Virus of Hog-cholera.—The etiologic factor of hog-cholera is an ultra microscopic organism capable of multiplying itself only in the body of susceptible swine. To such animals it is extremely virulent; experiments have shown it to be capable of producing disease if 0.00002 c.c. of a virus serum is injected.

In affected swine the virus is present in the blood and in all organs irrigated by the blood stream. It is abundant in the urine and has been found to be present in the bile and in the crystalline lens. The erythrocytes adsorb or carry the virus, at least it seems to be impossible to remove the final trace of it which adheres to the blood cells to the extent of rendering them avirulent. The virus is present also in the secretions of the conjunctival and respiratory mucosa. That it is less constantly demonstrated in the feces is probably due to the fact that either digestive or putrefactive influences bring about its destruction.

Introduced into the body of other animals the virus rapidly disappears so far as its presence can be demonstrated by the inoculation of susceptible pigs. There appear, however, to be exceptions to this general statement, for it has been found to survive in rats for several days and it persisted in goats for at least two passages. Its presence could be shown in four passages through peccaries and it may have made some development in this animal even if the latter showed not the slightest degree of susceptibility.

Contained in otherwise sterile blood or serum the virus retains its virulence when kept at room temperature for from 10 to 14 weeks. The sterile filtrate kept in the ice-chest remains virulent for several months as does also the virus when contained in chilled or frozen meat.

The virus endured if heated at 45 to 46° C. for 24 hours, but the virulence disappeared in about a week when it was kept at 37° C. It withstood heating at 58° C. for 2 hours, but an exposure to 60° C. lasting from 16 to 24 hours killed it. Its destruction is brought about in 1 hour at a temperature of 70° C. Desiccation to constant weight for 3 days failed to destroy the virus, and low temperatures apparently have no effect on it.

The virus of hog-cholera is quite resistant to chemical agents, although it is not known with certainty that protective influences of the media in which it is contained are not more responsible for this than any quality of the virus *per se*.

A mercuric chloride solution of 1 to 1000 parts of water mixed with virulent defibrinated blood in a proportion of 1 to 2 failed to destroy the virulence after an exposure of 3 days, and the same results were obtained with 5 per cent solution of phenol, mixed with the blood in a proportion of 2 to 5. A 3.3 per cent phenol solution was tolerated for 8 days. A 2 per cent formalin solution was endured for the same length of time. On the other hand, antiformin destroyed the virulence after a contact of 2 hours, and a 20 per cent hypochlorite of lime solution killed the virus in 1 hour. A 6 per cent cresol-soap solution required the same length of time to destroy it.

Various attempts to attenuate the virus have apparently shown that, when its pathogenic properties are diminished or destroyed, the antigenic and immunizing powers are correspondingly reduced.

The virus succumbs when it is contained in putrefactive media, but the periods necessary for its destruction vary considerably in accordance with the action of factors which determine the intensity of the

process of decay. Apparently the ambient temperature exercises a potent influence in this connection.

In four carcasses of swine, dead with cholera, buried during hot weather, the virus failed to survive after 2 weeks of burial. In another experiment it was found that, in one of the carcasses buried in a sandy soil, the virus survived for 8 weeks, but it had apparently been destroyed in 20 weeks. In a second carcass, similarly disposed of, the virus persisted for 27 weeks, but had disappeared at the end of the thirty-first week. A third carcass, buried in clay soil, still contained the virus after 34 weeks, but it had apparently been eliminated at the end of 36 weeks.

When two carcasses were left exposed on the surface during January and February without being covered in any way, it was found that in one the virus survived for 10 weeks and had disappeared a week later. In the other it endured for 11 weeks, but had been destroyed in 12 weeks.

Host Species.—There is no evidence which shows that any animal but swine is susceptible to the disease. The latter is strictly specific for swine, the only animal in which the virus appears to be capable of multiplication in a degree sufficient to display its pathogenic qualities.

Modes and Vehicles of Infection.—Swine which are actually sick with hog-cholera or in which the disease is in incubation constitute the primary source of infection and serve as the most frequent means by which it is disseminated. Sick hogs escaping from neighboring farms or newly purchased stock as well as swine returning from fairs and shows have always been common factors in the country-wide distribution of the disease.

The virus is discharged from the body of such swine in the urine, the feces and the secretions of conjunctival, nasal and bronchial mucosa. This virus elimination begins quite early in the period of incubation. In a pig infected by subcutaneous inoculation, it was found that the blood and the urine were already virulent on the first day after the injection, the feces were infective on the second and the eye and nose secretions on the third day. Yet the animals used in this test showed no visible symptoms until the fifth day after becoming infected.

It is probable that such materials remain virulent during the entire course of the disease and, depending on the nature of the environment into which they are voided, for varying periods after they leave the body.

It is impossible to define with any degree of exactness the length of time during which the virus of hog-cholera persists in a virulent form after its deposit on the soil, stable floors or in the surface water of pig lots and pastures. Evidence shows that the biologic processes in soil and water and the putrefaction of the media in which the virus is contained are more or less detrimental to its existence, but these factors are so complex and variable that no precise statement can be made in regard to their action on the virus.

It is, however, quite certain that the prevailing temperature exercises a potent influence on the longevity of virus outside the animal body. The infection in yards and similar places is more likely to disappear quickly in summer than in winter, and as a general rule, the introduction of susceptible swine on previously infected premises cannot be regarded as safe until at least 3 or 4 months of warm weather have elapsed since the last diseased hogs were removed.

Although the infected hog and the free movement of swine in transit are in the largest measure responsible for the spread of the disease, there is no doubt that certain factors, as yet unknown, may also play a part. Occasionally extensive outbreaks involving a considerable area occur which cannot all be charged to movements of infected swine.

In certain cases, the reckless use of virus for immunizing purposes may be held responsible for the spread of disease, but such occurrences must be quite exceptional.

The part played by the mechanical carriers other than swine has always received consideration. It is quite conceivable that the virus may be transported in small particles of soil or filth on the feet of persons or animals or by litter dropped from vehicles, but its regular occurrence has been difficult to prove by experimental methods. In one such trial in which pigeons were used, infection was not transferred from the sick pigs to the healthy, susceptible ones by these birds, although they moved freely from one pen to the other.

House flies, however, fed on the eye secretions or the blood of sick pigs may harbor the virus for some days at least, but the negative results of transmission experiments with such flies throw doubt on the probability that the house fly is an important factor in the transmission of hog-cholera from farm to farm even if it would not be reasonable to exclude the possibility altogether.

The blood-sucking stable fly may take up and harbor the virus and under favorable conditions may transmit it, but no evidence shows that this fact can be held accountable for a wide dissemination of the

disease. Yet the checking of very active outbreaks of hog-cholera with the advent of freezing weather is warrant for not altogether rejecting some biologic vehicle of infection as a factor in its dissemination.

The infection may be carried by streams, but it is highly probable that floating carcasses and slaughter-house offal are more responsible for the spread of the disease than a diffusion of virus in the water itself.

The feeding of kitchen garbage to swine may cause outbreaks of cholera. Many swine reach slaughtering establishments during the period of incubation, and as in such cases the disease cannot yet be recognized by the inspectors, it is quite obvious that meat products containing the virus must find their way into the channels of commerce.

Although there are cases in which healthy pigs, which were not visibly affected with the disease and which, upon post mortem examination, show no lesions, are found to harbor the virus, there is no considerable volume of evidence to prove that normal carriers play an important part as infection vehicles.

Natural infection apparently comes about by the introduction of the virus into the alimentary tract and especially through the agency of the markedly virulent urine. That virulent secretions of the various mucosa may also play a part cannot be doubted.

Virus deposited on the conjunctiva, on abrasions of the skin, or brought in contact with the respiratory mucous membranes may also give rise to positive infection.

The incubation period ranges between 4 and 17 days, during which time the animal concerned is already infective, the disease thus being contagious during its entire course.

Factors Favoring Infection.—Many conditions have been mentioned as having a predisposing influence in the etiology of hog-cholera. Such influences are attributed to improper feeding (new corn), damp or cold sleeping quarters and unsanitary surroundings. In a general way, all these factors are objectionable from a sanitarian's viewpoint, but nevertheless it seems extremely doubtful in the light of our present-day knowledge that they influence the development of cholera in susceptible pigs in the least.

Certain precautions may prevent virus from being introduced into a herd of swine, but once they have been actually exposed to the infection, morbidity and mortality rates in groups of susceptible swine will not greatly differ, whether the animals are kept under good

management or under a faulty régime of feeding and maintenance. In a more indirect manner, however, the adverse factors mentioned may influence the susceptibility to hog-cholera of swine which were previously immunized or which are in process of acquiring immunity by the prevailing method.

Unsanitary living conditions and probably faulty feeding also are potent contributing factors in the etiology of disease induced by the *Bacillus suipestifer* or by other colon-typhoid intermediates. These organisms, commonly part of the intestinal flora of healthy swine, are particularly apt to have their pathogenic powers exalted when their hosts become infected with the filterable virus of hog-cholera.

Frankly pathogenic to the younger swine, these germs far less commonly produce disease in older hogs, but if the latter become infected with hog-cholera their resistance may disappear, and in the rôle of secondary invaders, they may supplement the purely septicemic character of the primary disease by causing tissue damage of a more local character.

Conversely, there are indications that swine primarily immune to cholera may have their immunity impaired when they become infected with *Bacillus suipestifer* or other closely related organisms. This may be particularly the case with young swine, and it is significant that suipestifer infection (pig typhus) is not infrequently observed in immunized pigs belonging to herds in which so called "breaks" have occurred.

The development of cholera in young, protected pigs, or their failure to acquire a solid immunity after the simultaneous serum-virus treatment, instances of which are occasionally reported, may, at least in part, be due to the same cause, and there is reason to suspect that the prevalence of pig typhus on certain farms may account for disappointing results after vaccination.

Thus, so far as proper sanitary environment constitutes the best protection against disease caused by bacteria which have a certain reciprocal relation to the ultramicroscopic virus, it must be recognized as a predisposing factor in connection with hog-cholera.

After sufficient contact, practically all swine contract the disease if susceptible at all. In regions where the disease is not enzootic, there is but little evidence of a special predisposition, and young as well as old animals readily become infected. In areas where the disease is a more or less constant feature, some of the older animals may escape disaster; this resistance may be attributed to an immunity acquired early in life when, as pigs, they became infected while they

were enjoying a passive immunity imparted by the milk of an immune dam.

Epizootological Considerations.—Hog-cholera, owing to the facility by which it can be transmitted and to the extreme virulence of its etiologic factor, is prone to occur in far-flung epizootics, wherever the swine population is dense and numerous enough to support them. In regions where the growing and fattening of swine is a necessary concomitant of the prevailing type of agriculture, the disease commonly constitutes a perennial problem.

Through the extensive corn-producing area of the Mississippi watershed with its enormous swine population, hog-cholera has found a permanent center of infection; in this region the disease is always

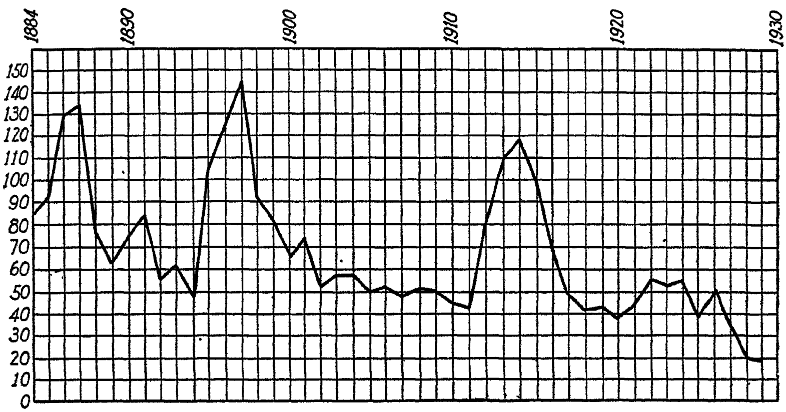

FIG. 75.—The periodicity of hog cholera in the United States. (Deaths per 1000 swine.)

apt to make disastrous inroads among swine which have been permitted to retain their susceptibility.

This influence of concentrated numbers of swine is well shown by the almost complete disappearance of hog-cholera from Germany during the war period when the larger feeding and fattening establishments were suspended under the stress of circumstances. In districts with a sparser swine population, the prevalence of hog-cholera is always less; but wherever susceptible hogs are being transported, the risk of infection must be reckoned with.

However, even in regions in which a stable number of hogs is being maintained, the morbidity varies inasmuch as the disease is apt to show marked exacerbations of prevalence. For a number of

years the disease becomes ascendant, attaining a maximum morbidity during a given year, and then recedes to a minimum level of prevalence. The zero point, so far as the United States is concerned, has seemingly not yet been reached, so that during periods of minimum morbidity the virus continues to maintain itself in a series of natural hosts.

The periodic fluctuations are particularly to be observed in the regions having a dense swine population, and from there they are

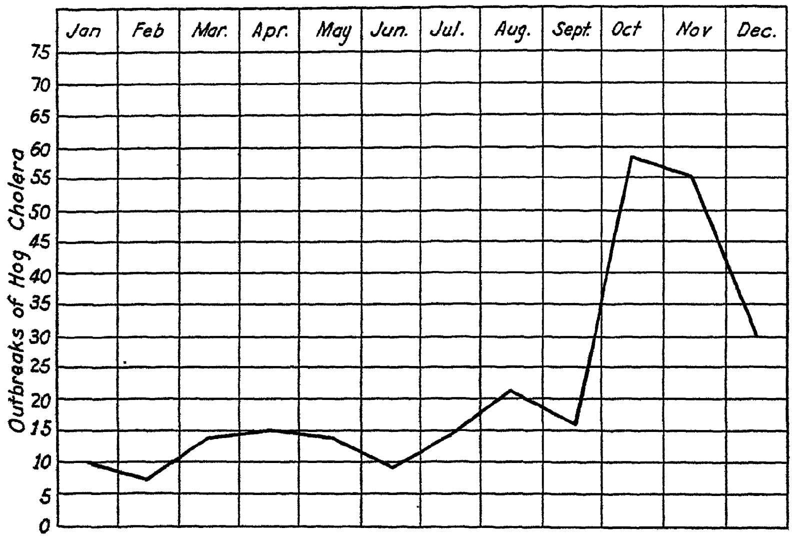

Fig. 76.—The seasonal incidence of hog cholera. (After Dorset.)

extended also to the other areas where the disease is normally not enzootic.

More regular than this periodicity is the seasonal influence to which the disease is apparently subject. From early summer, the morbidity rate increases; it reaches its maximum during autumn, and in the winter and early spring it attains its lowest point.

During the colder portion of the year the means for a wide dissemination are lacking, and whatever spread takes place must be attributed to more direct, actual contacts. The latter, as well as the virus preserved in the cold and thus biologically inactive soil, constitute the connecting link between outbreaks of one year and those of the year succeeding. In the period of low morbidity, the disease, as

a biologic phenomenon, is probably most vulnerable to attempts at eradication.

In individual outbreaks the march of infection may show considerable variation in behavior. In certain infected herds the new cases are most numerous early in the outbreak, whereas in others the infection gains momentum as time progresses. The latter type of behavior is the more common. Not infrequently no new cases occur for one or two weeks after the first animal succumbed, but from then on the rate of spread may become a geometric one.

The volume of virus initially introduced, the opportunity for and the nature of contacts can be regarded as the factors which exercise the greatest influence in determining the course of the infection throughout the group of swine involved, at least so far as the animals have not been deprived of their specific susceptibility.

Prophylaxis.—Wherever hog-cholera has assumed an enzootic character its prophylaxis is a problem to be solved on every farm. It has as yet not been possible to seriously contemplate its eradication, although on theoretic grounds this lies within the range of possibility. The latter is dependent on the co-ordinated and persistent effort of all swine owners. While awaiting such an attempt, each herd owner must depend on his own foresight and action.

In the past, the control of hog-cholera was approached in many ways, ranging between the administration of impossible and absurd cures and the more rational application of general hygienic measures.

All such attempts, even the latter, were followed by failure, and it was not until Dorset, McBryde and Niles worked out a feasible method of immunization that a foundation was laid upon which an effective prophylaxis could be erected.

In the regions where hog-cholera exists in an enzootic form, immunization is the pivot upon which the solution of this perennial problem must turn. In sections where the disease occurs sporadically, other means may sometimes be sufficient. The ordinary hygienic measures must never be neglected under any circumstances, even in those where density of swine population and a high rate of morbidity renders immunization imperative.

As in many other transmissible diseases, the methods of prevention of hog-cholera are largely determined by the morbidity and prevalence rates peculiar to the area concerned.

Elimination of Infection Sources.—Attempts to eliminate the source of infection, that is the diseased animal, are relatively more important in regions where the disease occurs sporadically in widely

separated herds than in those where it is permanently established. In the latter, but little can be accomplished by the application of such radical measures as the compulsory destruction of diseased or exposed swine. The cost would be prohibitive, and aside from this such measures would seriously derange farming enterprises.

In districts ordinarily free from the disease, the destruction and adequate disposal of the herds involved in an outbreak may be the most suitable method of procedure, especially if all healthy swine on neighboring farms be protected by a passive immunity conferred by the use of antiserum. Under such circumstances, such a procedure may be preferred to the process of active immunization inasmuch as the promiscuous use of virus in otherwise disease-free areas is always accompanied by the hazard of establishing new centers of infection.

The radical method is successfully applied in the Dominion of Canada, but cannot be depended on in the extensive areas where the disease is more or less permanently established in a dense swine population.

Of special importance in all regions is the sanitary police supervision of all swine in transit. It is, no doubt, a sound and most effective practice to exclude from traffic all susceptible swine unless they are being transported for the purpose of immediate slaughter. Hogs shipped to and from fairs or stock shows as well as those which enter traffic as feeders should be adequately protected by immunization.

Garbage and kitchen wastes containing pork scraps, ham bones and the like, of an unknown origin, must not be fed to susceptible swine unless rendered safe by cooking, inasmuch as such products, for reasons already stated, may contain the virus in a viable state. It is also obvious that carcasses of animals dead with the disease must be disposed of in accordance with methods described in another chapter.

Destruction of Virus.—The virus present in the soil and in stables may constitute a source of danger to susceptible swine. Its destruction comes about by biologic processes, but as these are influenced by numerous factors, the time required for its completion must necessarily vary. In cold weather the virus is apt to linger, whereas in warm weather it is more readily destroyed. As a general rule, the introduction of susceptible swine on previously infected premises is a hazardous procedure unless at least 3 or 4 months of warm weather have elapsed since the removal of the last sick animal. In the areas

where active immunization is practically the only means of protection, this should certainly be practiced in all cases in which new stock is to be introduced on previously infected farms.

The destruction of virus by disinfection as ordinarily practiced is but uncertain. No doubt, concentrated disinfectants on well-constructed and impervious floors or runways may be effective, but in yards and litter their value is more or less illusory.

Immunization.—That swine which recovered from hog-cholera had as a consequence acquired a very solid immunity was known for many years. It could also be shown that the blood serum of such animals when injected into experimental pigs had some protective properties although not sufficient to meet the actual requirements of disease control.

As a sequence to the discovery that an ultramicroscopic virus always abundant in the blood of acutely diseased hogs is the primary etiologic factor, it was found by Dorset and his co-workers that the injection of quantities of such virulent blood into immune swine so reinforced or exalted their immunity that their blood could be used as a means to protect swine against natural as well as artificial infection.

Since this discovery, the defibrinated blood or blood serum of such hyperimmunized swine has become the most effective, probably the only, means which in a large measure has enabled swine growers adequately to protect their herds.

Used by itself, the hog-cholera antiserum confers a substantial, passive immunity. This, however, is evanescent, and may endure for only a few (3 to 6) weeks. If, on the other hand, during the validity of this passive immunity, the animal concerned is either exposed to the infection or receives a small quantity of virulent blood, an active immunity results which may last for several months, if not for a lifetime. Properly prepared and kept in suitable storage, the antiserum retains its immunizing qualities for years.

In actual prophylaxis, either a passive or active immunization is applied according to local conditions or circumstances. Passive immunization by antiserum alone is applicable principally for swine which require protection for a brief period only, such as those which are ready for market or which may be exposed to the disease for a short period. It is also used in actual outbreaks for swine in the very early stages of the disease.

In sections where eradication by slaughter is an established practice, the swine of neighboring farms are commonly rendered pas-

sively immune by means of a serum injection; this protection is adequate if the infection focus has been completely destroyed.

The simultaneous serum-virus injections as a means of securing an enduring immunity have proved to be the most effective in the areas where large numbers of swine are perennially menaced by hog-cholera outbreaks. No doubt, the reckless or incompetent manipulation of virus or a faulty immunization technique has occasionally been followed by bad results, but notwithstanding these, the simultaneous method of vaccination has been very successful, and it is very doubtful that it can be materially simplified or improved.

That, in the regions where hog-cholera is enzootic, no advance has been made toward the ultimate suppression of the disease is not a reflection on the value of this method of protection, but must be ascribed to the fact that it is applied to only a relatively small proportion of the hog population. If used, it results in the saving of swine which otherwise might have been lost.

Wherever hog-cholera occurs enzootically, it is essential that vaccination by the simultaneous method be annually practiced as a matter of routine. It should preferably be done rather early in the season, when, owing to the smaller sizes of the swine, immunity can be secured with a minimum of material.

All susceptible swine on a given farm should be subjected to the treatment inasmuch as hogs so treated may occasionally eliminate the virus for a number of days and untreated hogs may be endangered thereby.

Now and then untoward results (breaks) are recorded, but they rarely occur provided that a potent serum and active virus are used in suitable quantities and that the inoculation technique is without fault.

In herds already involved in the disease, immunization results may fall short of expectation, and the same may happen in groups of young swine affected with pig typhus or infectious enteritis. None of these undesirable results detract from the value of a method by which millions of swine are annually saved.

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CHAPTER XXXIX

FOWLPEST

FOWLPEST is an acute, infectious disease of poultry, septicemic in character and usually fatal. Fowlpest was confounded with fowl cholera until 1878, when its specific entity was demonstrated by Perroncito.

The disease appears to be enzootic in northern Italy where, by its highly malignant character, it has caused great havoc in poultry flocks. From its original focus it has repeatedly invaded other countries of the European continent, and outbreaks have also occurred in this country, in South America and in parts of China.

Fowls affected with pest show an initial dullness, loss of appetite, ruffled feathers, and edema of the head and throat. The comb and wattles, frequently, although by no means constantly, show evidence of cyanosis, and the afflicted fowls are apt to die in a state of coma. Diphtheritic lesions may be observed to be present in the mouth and pharynx; paresis and diarrhea may also be manifest.

The disorder is usually fatal; the death-rate commonly reaches 100 per cent of the affected birds. The rare birds in which the disease is followed by recovery have acquired a substantial immunity which can be passively transmitted by their serum to healthy poultry.

In most of the affected animals the disease runs its course in 2 to 4 days. Cases of longer duration are relatively rare, but have been observed to linger as long as 9 days. Apparently the infection is not subject to any of such influences as those of age, season or breed.

Susceptible Species.—Owing to apparent differences in the pathogenicity of the virus toward various avian species, experimental attempts to show the susceptibility of the latter have not always yielded constant results. Fowls and turkeys show the highest degree of susceptibility and usually do not fail to contract the disorder in outbreaks. Pheasants, guinea fowls, sparrows, and parrots are generally classified among the susceptible bird species, and hawks and owls have also been observed to yield to artificial infection.

The pigeon is not constantly susceptible; some of the animals suc-

cumb to the inoculation, whereas others do not. However, this species has been observed to sicken after naturally acquired infection.

Water-fowls appear to be more resistant, and spontaneous disease in ducks and geese is certainly rare. Experimental inoculation of these birds has not always yielded constant results, but on the whole, ducks appear to be more resistant even than geese.

Mammals are constantly refractive; inoculation experiments with rabbits, cavias and mice failed to induce disease.

The Virus of Fowlpest.—The virus of fowlpest consists of an ultravisible, filterable micro-organism. Various observations warrant the conclusion that the virus has a tendency to adapt itself to certain avian species. It was shown that a virus obtained from ducks was avirulent for fowls, and that a chicken virus failed to infect ducks.

Kraus and Loewy experimented with a virus obtained from fowls, finding that it was inactive when inoculated into old geese. The specific relationship of these two strains was shown by the fact that old geese inoculated with a fowl virus failed to sicken, but were later found to be resistant to the virulent goose strain. The contradictory evidence obtained in susceptibility experiments may be entirely due to the variations of which the ultravisible micro-organism is capable.

The specific virus of fowlpest is present in all organs and parts of birds at the height of the malady as well as those of animals which have recently died of it. The virus can be readily demonstrated in the blood, the naso-pharyngeal mucus, the serous fluids, the bile and the feces. It was also found to be present in eggs.

Experiments undertaken to ascertain the resistance of the virus to various external influences have not always yielded constant results. This is probably due to various factors, the action of which cannot always be measured.

It was found that the blood of fowls dead with pest, when stored in a dark ice-chest, retained its virulence for months. In a suspension of physiologic salt solution the virus was still alive and active after a period of 7 weeks. Sealed in glass ampoules and kept in a refrigerator, the virus retained its virulence for 1 to 1.5 years. Jouan and Straub found the virulence intact after a storage of 35 days at 37° C. Contained in sealed glass tubes and stored in a dark place, virulent blood was proved to be still pathogenic after 7 to 8 months.

The virus resists drying for some time. Desiccated pieces of organs were found to be virulent after 3 to 5 weeks' storage. Another observation showed that dried blood retained its virulence for 22 days if kept in the dark, but when it was exposed to diffused daylight for

15 days it was found to be no longer disease producing. A thin layer of blood dried on a glass slide and kept in the dark at room temperature remained virulent for a period of 100 days.

Blood dried in a thin layer, sheltered against light, at temperatures of 21 to 28° C., was virulent after a storage of 9 days; dried liver still could cause disease after 19 days, and dried spinal cord kept in the dark at 20° C. still could produce disease after 233 days.

The etiologic factor of fowlpest is rather sensitive to light; the virulence of inspissated blood exposed to daylight at a temperature of 28° C. had disappeared after 40 hours.

The fowlpest virus in putrid material survived for 3 weeks. According to another observation its virulence soon disappeared in the presence of a slight degree of putrefaction, but it was likewise shown that it may resist decomposition for as long as 39 days.

The virus does not resist heat for a great length of time. It became somewhat attenuated after an exposure of 44° C. for 24 hours, and even at 46° C. it was not yet killed after 2 days. It was killed after 3 days at 47° C., and it resisted an exposure of 55° C. for only ¾ hour. Ten minutes at 60° C. were sufficient to kill the virus. A heating of 5 minutes to 65° C. had the same result, and at 70° C. it was killed in 1 to 2 minutes.

Most of the common disinfectants are destructive to the virus, especially when applied in hot solution. A solution of mercuric chloride (0.1 per cent) killed it within 30 minutes. Ten minutes only are required for its destruction by sulphuric acid (1 per cent), caustic potash (2 per cent), calcium hypochlorite (3 per cent) and phenol (4 per cent). Hot solutions of a saponified cresol (5 per cent), or mercuric chloride (1 per cent) have been especially recommended for disinfecting practices.

The virus of fowlpest is quite resistant to glycerin; it remained intact for 3 to 5 months in a 50 per cent aqueous solution of this substance.

Modes and Vehicles of Infection.—The results of transmission experiments have not always been constant and have not always been followed by the development of the disease. It is quite probable that the contradictory results, here and there observed, were caused rather by lack of virulence of the material used than by the modes of infection employed.

The infectiveness of fowlpest virus may be extraordinarily marked; it has been found possible to induce the disease by injection of 4 c.c. of a 1–125,000,000 dilution of the blood of a fowl affected

with the disorder. It is known that a passage from fowl to fowl is apt to exalt virulence; workers who experienced no difficulty in bringing about fowlpest in their experimental subjects may have used a virus of maximum pathogenicity whereas others may have used material of reduced infectiveness.

Jouan and Straub readily caused pest in fowls by administering the virus *per os*. If fully virulent material is introduced into susceptible birds, the disease follows, no matter what mode of inoculation is employed. It must be admitted, however, that some unknown factor may have an influence in the transmission of spontaneous pest.

That the virus is ordinarily conveyed by the feces and the nasopharyngeal secretions is commonly accepted. In the transmission of the disease, the food and drinking water can readily serve as vehicles. Some authors are of the opinion that, aside from contact infection, living carriers and, possibly, objects making indirect contact must be given consideration. No doubt, the virus may be transported for considerable distances by the susceptible sparrow. It may also be conveyed by eggs used for hatching purposes; and the part played by blood-sucking parasites, though not definitely proved, is well within the range of possibility.

The mucosae of nose and throat and of other parts have been pointed out as suitable ports of entrance, and that the virus may also enter by means of wounds and abrasions of the integument is obvious enough.

The period of incubation ranges between 3 and 4 days.

Prophylaxis.—Although immunity to fowlpest has been experimentally induced, no method of immunization applicable to sanitary practice has thus far been developed.

In regions where fowlpest is enzootic or where it has been recently introduced, the isolation of flocks in properly constructed enclosures may be attempted with profit. If, in doing so, all contact with flying birds can be excluded, such a measure would constitute an additional advantage.

Special care must be exercised in regard to new fowls. All new purchases should be kept in safe segregation for not less than 2 weeks, the last one in company with one or more healthy test fowls.

Once the disease has broken out in a stock, its prompt and complete destruction is the most valuable method of preventing its extension over a greater area. Individual birds of great value may be segregated at once after the malady has been diagnosed, but this should be attempted only in very exceptional cases.

In countries and areas where the disease is first introduced, the destruction of infected or exposed flocks is imperative from a livestock sanitary point of view, and the sooner this is accomplished the less costly will the solution of the problem be.

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CHAPTER XL

AFRICAN HORSESICKNESS

AFRICAN horsesickness is a transmissible, septicemic disease of equines caused by an ultramicroscopic, filterable virus and characterized by a very high mortality rate.

It is probable that the malady was first observed in 1569 by the Padre Monclara in the course of a voyage to East Africa. A more definite account of the disease dates from 1719 when it was mentioned in an official document of the Cape Colony government. Since then the disease has been frequently reported as occurring in more or less disastrous outbreaks in South Africa. McFadyean, Theiler and other investigators, during and since the last decade of the nineteenth century, occupied themselves with the problem connected with horsesickness, defined its character and ascertained the nature of its etiologic factor.

Horsesickness is almost entirely confined to the African continent, where it assumes a virulent and epizootic character particularly in the regions near the equator. It has frequently asserted itself in the territories further south, and there also it has been responsible for severe losses of horse stock.

The disorder must be regarded as a septicemia, in the course of which toxic substances are elaborated which have a specific affinity for the endothelia of the capillary vascular system and are the determining factors in producing the tissue damage responsible for the morbid manifestations which characterize this entity among equine disorders.

In its clinical aspects, horsesickness presents itself in forms which are described as per-acute, acute and sub-acute. The per-acute cases constitute about 30 per cent of the total. In this form of sickness, the animals, after a very brief period of incubation, show a rise in the body temperature and commonly succumb within a few hours after presenting evidence of marked restlessness, muscular trembling and terminal collapse.

In the acute form of the disorder, named "dunkopziekte" by the

Africanders, which supplies approximately 40 per cent of the cases, dullness and fever usher in a general and progressive depression, accompanied by marked pulmonary and cardiac impairment.

The sub-acute form prevailing in about 30 per cent of all cases is marked by a less rapid evolution and is especially characterized by the appearance of edematous swellings in various parts of the body but most notably of the head and neck and hence spoken of as "dikkopziekte." The edematous filling and enlargement of the tissues of the supra-orbital fossae is especially pathognomonic of the dikkop form of the malady. Cases of the latter present a marked muscular weakness or atony, and the animals involved can only with difficulty maintain themselves in the standing posture.

All forms of horsesickness show a very high mortality rate; this usually ranges between 90 and 100 per cent of the affected animals. The more acute forms of the disease are always the most likely to be fatal.

The more conspicuous among the after-death appearances are the frothy masses of respiratory exudates filling and protruding from the nares, and the edematous swellings about the head and neck. The mesenteric, bronchial and mediastinal lymph nodes are enlarged and edematous. The liver and kidneys are swollen; the gastro-intestinal mucosae are hyperemic and often marked by hemorrhagic areas. There is edema of the lungs, and a clear, yellowish exudate is present in the pleural cavity. The pleura is covered by a thick, grayish yellow, fibrinous exudate, and cardiac changes are often to be observed.

In the regions affected by horsesickness, the malady has often caused appalling losses and must be regarded as one of the major scourges of an equine population. In the horsesickness epizootic of 1845–55 the malady destroyed 64,850 horses of the total of 160,784 then present in the Cape Colony alone.

Susceptible Species.—Under natural conditions, horsesickness affects only the equidae. Horses, mules and asses sicken after natural exposure, the susceptibility declining in the order named. Horses are very susceptible, asses but slightly so, and mules occupy an intermediary position with reference to their liability to sickness infection. In the horse, the disease is usually very malignant, less so in the mule, whereas in the ass the disorder is benign and fatal cases are but rarely observed.

The zebra is considered to be susceptible but shows the malady only in a very benign form, if at all. The susceptibility of the quagga is in doubt.

Goats and sheep have been reported as having become infected by artificial methods, but similar attempts with cattle, swine, cavias, rabbits, rats, cats, fowls and pigeons have yielded negative results only. Man seems to be refractive to the virus of horsesickness.

Dogs are susceptible to artificial infection and may also contract the disease by devouring the meat of horses which succumbed to it. In connection with the susceptibility of the dog, it has been suggested that the jackal, generally distributed in many parts of Africa, may have to be considered as an infection reservoir.

The virus of horsesickness is an ultramicroscopic organism, demonstratable in the blood, serum, exudates and the various organs of animals affected by the disease. The urine also has been found to be infective. The virus cannot be separated from the erythrocytes by oft-repeated and prolonged washing. Always present in the blood serum at the height of the disorder, the virus cannot be removed from it by a centrifugation of 12 hours' duration.

The virus of horsesickness is endowed with a marked resistance to a number of external influences. Contained in defibrinated blood it retained its virulence during a period of 4 years. Decomposition of the ambient medium does not appear to affect the virus; it remained pathogenic in putrid blood for more than 2 years.

Drying for 12 to 24 hours destroyed the virus, but as long as a trace of moisture remained, the virulence was retained. It is sensitive to direct solar radiation and is killed by it in a relatively short period. Heating for 6 days at 45° C. failed to destroy the virus, and on a water bath at 50° C. for 5 minutes its virulence was retained. A similar exposure at 70° C. killed it.

Solutions of phenol (3 per cent), sodium taurocholate (5 to 10 per cent), saponin (5 to 10 per cent), failed to destroy the virus, and when kept in the bile of a rabbit it was not injured.

The virus of horsesickness may be kept for years when contained in 1,000 parts of defibrinated, virulent blood mixed with 1,000 parts of water, 1,000 parts of glycerin and 1 part of phenol.

Mixed with a 5 to 10 per cent solution of lecithin and then injected into a susceptible animal, the virus fails to produce disease. Subjects so injected do not become immune, and when the virus is separated from the lecithin and injected into a susceptible horse it promptly shows its virulence.

Modes and Vehicles of Infection.—The fountain-head of horsesickness infection is the animal actually sick with the disease. From such an animal the malady can be readily transmitted by means of

subcutaneous, intravenous, intraperitoneal and intratracheal inoculations. The blood is the most suitable inoculum to be used when attempting artificial infection, and in the case of the more virulent strains 0.0001 c.c. of blood may be sufficient for the purpose. If the virus used belongs to a less virulent strain or has become impaired by age, transmission is still possible if larger amounts are injected.

In spite of the marked susceptibility of the horse to sickness and the high degree of pathogenicity of the virus, the malady, under natural conditions, is not transmitted by direct contact. Infection of the fetus *in utero* by a diseased mother, however, appears to be quite possible.

How horsesickness is actually transmitted is, at this time, not precisely known. There is, however, among observers, a general agreement that the malady is transmitted by a blood-sucking vector. This belief is largely based upon knowledge empirically acquired. It finds also some support in experimental evidence.

Pitchford infected a horse with mosquitoes of the genera *Anopheles* and *Stegomya* which 48 hours earlier had sucked the blood of a sick animal, and a similar result with *Stomoxys calcitrans* was reported by another observer. Reinicke produced the disease in a horse in Germany by the use of an extract prepared from ticks collected from sick horses in Southwest Africa. These results may, at least, indicate the possibility of transmission in a purely mechanical manner.

Observations made in the field indicate that the vector is a night-flying insect. Theiler suspects that species of mosquitoes may serve as active carriers of the virus, and his views derive support from the fact that horses absolutely protected against attacks by these insects do not contract the disease even in areas where an outbreak of horsesickness is in progress. In this connection, it may also be significant that the spread of horsesickness ceases shortly after a frost, a phenomenon reminding one of a similar epidemiologic behavior of another mosquito-borne disease, yellow fever of man.

Infection *per os* can probably be excluded from the problem because of the large doses of virus required to infect animals with horsesickness by this method.

The incubation periods of horsesickness range between 3 and 14 days in length, the shorter ones pertaining especially to the more acute forms of the disease.

It is not known in what manner and where the virus maintains itself between the seasonal appearances of horsesickness. Apparently it disappears from animals after recovery, and chronic virus carriers

have thus far not been revealed. Theiler suggests that some animals, not belonging to the Equidae, may serve as a virus reservoir. On the other hand, it does not appear to be altogether impossible that the winter virus, if so it may be called, may have to be searched for in the dormant forms of the unknown vector.

Factors Favoring Infection.—Horsesickness is a pasture or out-of-door disease, subject to seasonal influences in districts where seasons prevail. In equatorial or tropical regions the disease may be encountered throughout the year. The seasonal incidence of horsesickness is largely associated with warmth and humidity. These factors also tend to determine the differences in morbidity shown from year to year. Seasons marked by a heavy sickness incidence may also be remembered for their heavy rainfall.

The topography of the land has a marked influence on the prevalence of horsesickness. Coastal areas, low, swampy lands, valleys and bottom lands are particularly prone to show a marked sickness incidence during the warmer months of the year. In sickness territory the lower land may present a serious hazard while nearby high ground may be entirely exempt. As a rule, the further removed from the equator and the higher the altitude the less prominent is the danger connected with the malady.

Infection chances are particularly great among horses pastured at night or during the morning hours when the grass is wet with dew. On the other hand, horsesickness morbidity is relatively low among horses kept stabled at night. The safest part of the day for susceptible horses to be out-doors in sickness territory is between 10 A.M. and 5 P.M.

In horsesickness territory, where seasons prevail, the disease ceases to spread with the advent of colder weather, and after a killing frost the disease, with the possible exception of a few sporadic cases, soon disappears. The Boers accept it as a general rule that 8 days after such a frost all danger is passed.

Horses which recovered from the disease are immune and are designated as having become "salted." However, this immunity is neither stable nor absolute. Exposed to the virus of another region than the one in which the infection was contracted, the "salted" horse may sicken again. Differences in the antigenic and pathogenic qualities of virus varieties appear to be associated with this phenomenon.

The immunity induced in some animals by recovery from horsesickness does not endure from one season to another. A certain num-

ber of "salted" animals may show relapses, and others become affected only when exposed in a particularly virulent outbreak.

If "salted" horses are removed from sickness territory or if kept sheltered against reinfection it is quite probable that their acquired resistance will be lost in a relatively brief period. The immune animals may, however, maintain their resistance if given the opportunity to be exposed to the infection under natural conditions while their immunity is still intact.

Differences in susceptibility are not conspicuous, but, on the whole, imported horse stock succumbs more readily to horsesickness than animals native to the districts where the disease is enzootic.

Prophylaxis.—Preventive measures may be based upon the facts that horsesickness is apt to be associated with certain localities and that there is good reason to believe that the malady is transmitted by a nocturnal vector.

If, in districts where horsesickness is prevalent, there are areas which, by their topography, are exempt from infection, advantage should be taken of these, as horses and mules may find sanctuary in such places. During epizootics of sickness, all solipeds susceptible to the disease should be moved to mountain pastures if this is at all practicable. As long as an infection hazard persists, low places near streams or other bodies of water should be avoided at night, and pasturing should be permitted only during the daytime.

If there is no safe ground where animals can be taken, they may effectively be protected by housing them during the night in stables so screened, or otherwise constructed, that mosquitoes can find no ingress. Whenever this measure is resorted to, it is advisable that the animals be stabled not later than 1 hour before sundown and that they remain there until at least 2 hours after sunrise. In emergencies, the use of smudges or the application of repellent mixtures may be attempted as temporary measures of defense.

Suggested by the general practice of dipping cattle for ticks, a similar treatment of the horse stock was tried in the hope that it may also prove to be effective against horsesickness. In a measure, this was successful in the milder outbreaks, but in the course of the more virulent epizootics the method made but little, if any, impression on morbidity.

Immunization.—Largely through the efforts of Theiler it was shown that the immunity acquired by "salted" animals and maintained by natural or artificial exposure could be utilized for the production of a very potent protective serum. Such a serum, when

injected into a susceptible animal, in an adequate amount, confers a passive immunity, which may be changed to an active one when virus also is simultaneously injected.

In the protective inoculation of mules, from 300 to 350 c.c. of serum is injected subcutaneously or intravenously, while 1 c.c. of virus is injected intravenously. The virus used is of the same strain as the one used in the hyperimmunization of the animals to serve as serum producers. Leipziger suggests a subsequent intravenous injection of 20 c.c. of virus.

In mules, the immunization is accompanied by a loss of 1 to 2 per cent of the animals treated, while later, as a result of natural infection, an additional 3 to 5 per cent may be lost.

The immunization of horses is much more difficult and must be undertaken with caution. According to Leipziger, 400 c.c. of hyperimmune serum and 0.1 c.c. of virus are simultaneously injected. Three weeks later the treatment is repeated with 100 to 200 c.c. of serum and 0.3 c.c. of virus. From then on, at daily intervals, virus is injected in decreasing doses down to 0.01 c.c. After that the virus doses are gradually increased until a reaction declares itself. If in the course of the treatment larger virus doses must be injected intravenously, the intervals between the injections must be appropriately lengthened.

In Theiler's scheme of immunization, 5 c.c. of a very weak virus is first injected in order to establish a degree of basic immunity. Six days later 3 c.c. of ordinary virus and serum are simultaneously injected. The dose of the latter is calculated at the rate of 0.75 c.c. of serum for every kilogram of body weight.

The losses which follow the treatment of horses amount to about 5 per cent, while, as a result of later infections, 5 to 10 per cent more may succumb to sickness. Thus, a loss of 10 to 15 per cent must be reckoned with.

All treated animals must be kept from work and be protected against exposure for a certain length of time. For mules, a period of 3 weeks is deemed sufficient; for horses 1 to 2 months is considered to be advisable.

If consideration is given to the fact that the losses of untreated animals in the field may amount to 95 per cent, it is evident that, in spite of the relatively high immunization losses, the treatment offers a decided advantage.

Another application of the immunity principle is based on the fact that the virus is transmitted to the fetus by the infected dam.

If the latter is "salted" and receives a moderate dose of virus toward the termination of her pregnancy the colt may thus acquire an active immunity.

Solipeds which become immune as a result of natural infection or of artificial treatment, in order to retain their resistance, should either be exposed in sickness territory or should receive annual injections of virulent blood. This procedure is of special value in regions where sickness exists enzootically. On the other hand, it is doubtful that the practice is indicated in districts where the hazard of infection is relatively slight or absent altogether.

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CHAPTER XLI

CANINE DISTEMPER

CANINE distemper is an acute, febrile, communicable disease of dogs, marked by an initial coryza, an irregular temperature curve, respiratory impairment, gastro-enteritis and disturbances of central nervous origin. Catarrhal and purulent manifestations of the mucosa are common in this disorder, and during its course such complications as broncho-pneumonia, nephrosis and gomerulonephritis, pustular exanthema, photophobia and corneal ulcers may be observed.

There is uncertainty with regard to its place of origin; some authors name Asia and others Peru as its original home. Apparently the disease was relatively late in making its appearance in Europe, and it was probably still unknown in England when the eighteenth century began. It was widely distributed in Western Europe in the last decade of that century and during the first one of the nineteenth. Even the far northern countries, including Greenland, did not escape invasion. About that time the malady was studied and described by Jenner. At the present time the disease is common in all the countries of the world, and in the larger cities distemper is the most frequent of all canine diseases.

Canine distemper is marked by a high mortality, the average death-rate amounting to 50 and 60 per cent. In Greenland and Iceland nearly all dogs were destroyed by it, and in England 90 per cent of the Japanese spaniels, 50 per cent of the Arctic breeds and the chow-chow, but in the Pekingese spaniels the mortality did not go beyond 25 per cent.

The disease, as a rule, runs its course in 3 to 4 weeks, although, in the more benign cases, recovery may take place in 8 to 10 days. The more malignant cases may end fatally within 3 to 5 days, but on the average there is a tendency for them to linger for a number of weeks.

Susceptible Species.—Dog distemper is peculiar to all canines, including wolves, foxes, jackals and hyenas. Ferrets and martens are quite liable to the infection. Many authors regard cats as also susceptible, but according to Laidlaw and Dunkin this must be

doubted; these investigators failed to secure positive results when they attempted to infect cats experimentally. The susceptibility of man must be denied; rabbits, cavias and white rats are also resistant to the infection.

The Virus of Canine Distemper.—Long before the advent of modern bacteriology the virulence of the nasal and conjunctival secretions had already been amply proved by experimental transmission of the disease either by inoculation or by the expedient of applying these substances to the nose and lips of susceptible dogs.

Since then a great number of microbic species has been advanced as the cause of canine distemper, but in no instance has such an etiologic relation been clearly demonstrated. At the most, such bacteria may have an influence on the character of the malady as secondary invaders, but they play no part as primary factors in causation. That such secondary invaders, in a dog deprived of its protective resistance by the primary etiologic factor, may exercise a most unfavorable influence on the course of the disease and its many complications can, however, not be seriously doubted.

In 1905 Carré succeeded in showing that canine distemper is caused by an ultramicroscopic, filterable virus, and his findings, since then, have been sustained by other investigators. The virus discovered by Carré apparently has a specific affinity for the myocardium and the serosa, and its presence could be demonstrated in the mucus of the nose, conjunctiva, blood, bile and peritoneal fluid.

From the initial stage of the malady, the volume of the virus increases until its height has been reached after which it ceases to propagate and it is gradually reduced during convalescence.

Virulent material stored in a cool place has remained infective for 4 months and apparently it is not destroyed by freezing; drying affects it comparatively slowly, attenuation becoming manifest only after a storage of 1 to 3 months.

It does not appear, however, that the virus maintains itself for long in a contaminated environment, and Gray could observe that some highly susceptible breeds of dogs escaped infection when they occupied places which were temporarily inhabited by dogs affected with distemper. No doubt, the ambient medium in which the virus is contained may exercise an influence on its longevity.

In another observation the virulent nasal discharge kept in the open air became inactive after 2 or 3 weeks. When it was mixed with glycerin and kept on ice, its virulence disappeared within a

few months; an exposure of virulent material to a temperature of 60° C. promptly caused its sterilization.

Modes and Vehicles of Infection.—Canine distemper, in its primary, non-complicated form, must be regarded as a septicemia which becomes exceedingly contagious owing to the virulent character of the initial nasal discharges. Carré showed that the affected dog is especially infective during the first days of sickness. This author is of the opinion that if a dog proves to be a virus carrier at a later period this feature must be attributed to the virus which, in a dry state, clings to parts of the body surface. The purulent discharges, which are so often a marked characteristic of the disease, as a rule, rapidly become harmless.

The conclusions of Carré are in a large measure supported by the experimental evidence submitted by Laidlaw and Dunkin. The affected dog itself plays a major part in the dissemination of the disease, and direct contact is the principal mode by which the infection is conveyed. Indirect contact by contaminated media, though also active as a means of spread, is of less frequent occurrence.

In the investigations by Laidlaw and Dunkin, evidence was obtained to show that the air in a confined space may serve as a vehicle for the virus for short distances, and that actual contact under the conditions mentioned is not always imperative to its transmission.

It is probable that the virus enters the body of exposed dogs through the air passages, but the possibility that contaminated food and drink may also introduce the distemper virus through the alimentary tract cannot readily be rejected.

Secondary infections by various microbic forms play a part in the various complications which are so common in canine distemper. *Per se,* they have no etiologic relation to the disease and can exercise their influence only when the normal resistance of the animal body has become impaired or canceled under the assault of the primary virus.

The period of incubation is usually stated to be from 3 to 7 days in length, with the extremes ranging between 2 and 20 days. Laidlaw and Dunkin found this period to be remarkably constant in their experimental cases. They occasionally found it to be as short as 3 days, exceptionally prolonged to 6 days, but in the great majority of their cases the disease declared itself 4 days after the infective contact.

Factors Favoring Infection.—Even though age is apparently a factor in susceptibility to distemper, it is quite probable that, after

all, dogs are equally susceptible no matter what their age may be. However, the disease is most common in dogs less than 1 year old, the majority of the cases occurring in the age group of 6 to 12 months. Inasmuch as dogs acquire a solid, even if not absolute, immunity after recovery from distemper, the apparent resistance of older dogs is probably entirely due to this factor.

In the large cities where canine distemper is usually enzootic, dogs either failed to survive the usual attack of distemper during their juvenile period or they recovered with a substantial immunity as a result. If dogs failed to acquire such a resistance by escaping the infection when young and are later exposed to it, they are as apt to contract the disease as during an earlier period of life.

Evidence is not lacking that dogs of all breeds are equally susceptible, even though it is commonly believed that the more refined, delicate and pampered races are more liable to contract distemper than the more vigorous breeds and mongrels. The former apparently show a much higher mortality rate than the latter after contracting the malady with an equal avidity. On the other hand, it is by no means impossible that injudicious feeding may increase susceptibility or at least reduce the capacity to overcome the effect of virus and that of the secondary invaders.

Arnous pointed out that the mistaken notion that a meat diet renders dogs more liable to distemper is responsible for harm; he even speaks of an increased susceptibility, and quite rightfully maintains that the dog, a typical carnivorous animal, can support its constitutional vigor better on a diet of meat and bone than on a vegetable or cereal régime of feeding. Constitutional vigor probably does not reduce susceptibility, but there is scarcely any doubt that it favorably influences the chances for ultimate recovery from the malady and its complications.

The evidence of seasonal influences on the incidence of the disease is contradictory. Some authors saw more cases during cold, damp weather and others during the warmer season. It is very doubtful that season has any effect on distemper morbidity at all. The latter, above all, depends more on the number of susceptible dogs and on the opportunity for contacts than on any other factor.

Prophylaxis. *Sanitary Measures.*—In the face of a disorder as ubiquitous and as readily transmissible as canine distemper the prevention of the disease by sanitary measures is almost impossible in places like large cities, which are scarcely ever free from infected dogs.

Where dogs are kept in a more isolated environment, such as remote farms and ranches, it is, of course, possible for them to avoid infective contacts. In cities this is more difficult to accomplish, but even there the segregation of young dogs may be attempted at least during the life period when they are least resistant to the infection and its sequelae. In any environment where canine distemper exists enzootically it is scarcely possible for a dog to escape the disease, but there is a certain advantage in postponing infective contacts to a more advanced life period during which the chances of recovery are apparently better.

Susceptible young dogs, that is all which have thus far failed to sicken with distemper, should be kept segregated and should at least be kept from boarding kennels, dog shows and other places where canines are apt to be assembled.

Attention to a rational régime of feeding, though probably of little or no influence on susceptibility, must, nevertheless, be recommended. The vigorous constitution of a properly nourished animal may not keep it from contracting the malady, but it is a decided asset in the reduction of mortality.

Immunization.—The discovery of various microbes alleged to be the specific cause of canine distemper was promptly followed by attempts to use these organisms for the preparation of vaccines and protective sera, but apparently these substances failed to bring about the specific immunity hoped for.

Attempts were also made to bring about a more benign form of the disease by the inoculation of the content of distemper pustules, nasal mucus and other virulent substances, and thus to secure the desired immunity. This may have been achieved in some of the animals treated, but the occurrence of fatal distemper in others could not always be avoided, and hence the method failed to find general application.

Skidmore and Buckley tested a proprietary substance alleged to have immunizing properties, but they did not divulge its nature or mode of preparation. They reported that it had some merit. Apparently, however, their test results were far less favorable than those claimed to have been obtained by the promotors of the product. It is possible, perhaps even probable, that the experiments of Laidlaw and Dunkin have brought the problem of immunization nearer to a definite solution.

Soon after Carré had shown that the etiologic factor of canine distemper is a filterable virus, he pointed out that, in order that vacci-

nation be effective, it must be specific with regard to the ultramicroscopic virus. Laidlaw and Dunkin fully confirmed Carré's discovery relative to the etiology of the disorder.

With this discovery as their base, they directed their experiments toward the immunological aspect of the disease and more particularly toward the discovery of a suitable immunizing agent. Using ferrets in their experiments, it could be shown that certain tissues taken from these animals at the height of experimentally induced disease contain large amounts of the specific virus which could be attenuated in various ways. In their experiments this was apparently best accomplished by the addition of formaldehyde. It was further found that ferrets injected with 2 c.c. of the attenuated tissue suspension tolerated a highly virulent inoculation made about 2 weeks later. In fact, such a virulent injection was shown to be necessary in order to establish a solid immunity. Immunity of a substantial character was thus secured in 90 per cent of the ferrets treated.

The ferret virus, however, was not effective when used to immunize dogs. If dogs were to be protected, much larger doses of the attenuated virus were required. Hence the experiments were continued by the use of virulent organ suspensions from dogs, prepared in the same manner as ferret material.

These experiments showed that with the attenuated canine virus it was possible to increase the resistance to distemper of the dogs treated, but the treatment failed to establish a complete immunity. However, if such dogs received a subsequent injection of living virus they acquired a solid immunity.

The experimental results were apparently confirmed by field trials. However, it will not be possible to estimate correctly the value of Laidlaw and Dunkin's procedure until the results obtained in actual practice can be properly evaluated.

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CHAPTER XLII

CATTLE PLAGUE

Cattle plague, also quite generally known as rinderpest, is an acute, transmissible disease peculiar to the ruminants.

Since ancient times the disease has been feared as one of the major scourges of neat cattle. From the beginning of the Christian era and during the Middle Ages, cattle plague, time and again, made inroads into the bovine population of extensive areas of the Old World, and even in modern times it has proved to be a more or less constant sequel of war and of the movements of animals. Especially when it invaded territories which had for a long period enjoyed freedom from the infection, did it occasion frightful losses, often resulting in an almost complete destruction of the cattle population.

The history of cattle plague, as well as the knowledge of its continued existence in a large part of the world, constitute to this day a most serious warning for all countries to be constantly on guard and to be ever prepared with the ways and means by which the disease can be effectively refused admission, and by which further dissemination can be prevented. Its potency for catastrophal results alone is warrant for the maintenance and support of a most highly developed livestock sanitary organization in all countries in which human existence is to any extent dependent on an adequate supply of milk and meat.

Cattle plague is characterized by a relatively brief period of incubation, the sudden appearance of a high body temperature and the presence of a severe hemorrhagic-catarrhal condition of all the mucous membranes, marked by diphtheritic erosions and pseudomembranes. Ulcerations are more rarely observed, and cutaneous lesions are sometimes also seen. The lymphatic organs always participate in the morbid process. The alimentary tract is usually most severely involved. Depression is marked from the beginning, and severe exhaustion and emaciation are common terminal features of the disease.

The mortality of cattle plague varies considerably with the territory affected, with the breeds of the cattle involved, as well as with the character of the epizootics. Inroads by the disease into western

Europe were accompanied by a mortality which ranged between 50 and 98 per cent. In central Europe certain outbreaks have been less disastrous, showing a mortality of from 50 to 60 per cent of the effectives. In southern Russia the cattle of the steppes are more resistant, and the losses amounted to from 30 to 40 per cent of the affected animals.

In the light of evidence presented by the history of the disease its economic importance is a preponderating one. In India its annual toll upon the cattle population exceeds that of any other disease, and the constant losses it occasions in China is the greatest drain upon its agriculture.

The heaviest losses were experienced during the eighteenth century when in Europe alone approximately 200,000,000 head of cattle succumbed to cattle plague. Denmark lost more than 2,000,000 head of cattle between 1745 and 1752. As a result of the epizootic raging in Bulgaria in 1877–78, two-thirds of the cattle of that country were exterminated.

The Virus of Cattle Plague.—The nature of the virus of cattle plague is as yet unknown. It belongs to the group of ultravisible micro-organisms which occupy a position on the borderline of filterability. It fails to pass through the bacteriologic filters commonly in use, but, no doubt, the density of the filters as well as the medium in which the virus is contained are determining factors. As a rule, the virus is classified as non-filterable.

The virus is always to be found in the affected animal; from the onset of the initial fever until death or complete recovery it can be demonstrated to be present in the blood, the various tissues, the saliva, the nasal discharge, the tears, the urine, the vaginal discharge and the feces.

Good evidence shows that the virus of cattle plague is quite fragile and that it rapidly loses its infectivity outside a susceptible animal. Feces and urine collected from animals during the later stages of the disease and stored in the shade at temperatures ranging between 54 and 73° F. retained their virulence up to 54 hours after collection, but frequently it was lost after shorter periods of storage. At slightly higher temperatures these materials were found to have become avirulent after a storage of 36 hours. Contained in a mixture of saliva and nasal discharge the virus survived for only 48 hours, when kept at room temperature.

In the soil, the virus survives for relatively brief periods. It failed to persist beyond 24 hours in corrals bare of vegetation but contain-

ing water. Susceptible animals became infected in such corrals within ½, 12 and 17 hours after the removal of animals affected with the plague.

Virulent urine diluted with water and sprinkled on the grass persisted in some instances for 36 hours, but not for a longer period, and when feces were used in a similar experiment, the grass was still infective 24 hours later. Another observation showed that feces and urine, diluted with water and kept in a vessel in a shady place, remained infective for 36 hours, but not longer.

Contained in small pipettes kept on ice the virus of the blood succumbed more slowly, but had lost its virulence after a storage of from 6 to 7 days.

In two observations the virulence of bone marrow was found to be retained for 9 days, but was lost after 15 days. Meat was shown to be infective after 3 days in one case and after 5 days in another, although the blood of the same animals had become non-infective after the same periods.

The longevity of cattle plague virus in storage may, however, be subject to variations. In one observation the blood of an infected animal had become avirulent after 3 days, whereas in that of another it remained infective for 51 days, in spite of putrefaction and ultimate desiccation.

Exposure to direct sunlight is fatal to the virus; when so exposed in a mixture of feces and urine its virulence had disappeared after 12 hours, but it persisted for at least 8 hours.

Drying destroys the virus after a short period; virulent blood dried for 4 days was no longer infective. Hides of infected animals no longer convey the infection if they are dried in the sun until they can no longer be folded.

Cattle plague virus is sensitive to heat, and the blood of infected animals kept at temperatures ranging between 36 and 40° C. had lost its virulence within 2 days. It is immediately destroyed when exposed to a temperature of 60° C. or higher. In putrefactive media the virus succumbs within relatively brief periods.

Many chemical substances destroy the virulence quite rapidly. The virus is very sensitive to acids and slightly less so to alkalines. Common salt added to virulent blood in a proportion of 1 to 10 kills the virus in a short time, and the addition of salt in the same proportion to green virulent hides renders them harmless in a few days. Glycerin destroys the virus slowly, but solutions of 2 per cent phenol or 0.1 per cent of sublimate do so quite readily.

Host Species.—Cattle plague is a disease peculiar to ruminants. These animals are not only most susceptible, but in the permanently infected areas of the world they serve as the host species by which the causative micro-organism is enabled to retain its place in nature. The bovidae are the most susceptible, but the wild ruminants, such as deer, buffaloes, antelopes, gazelles and others, are also liable to contract the disease. The degree of susceptibility may vary, but all are more or less subject to cattle plague infection.

Sheep and goats are less susceptible to cattle plague. In some epizootics which caused a heavy mortality among the bovine population, they generally escaped disaster even if they occupied the same stables with plague-stricken bovines. It was found in Indo-China, however, that goats proved to be good experimental subjects and that this susceptibility was nearly equal to that of the buffalo. Spontaneous infection of sheep and goats does occur, but is much more rarely seen than in cattle.

The camel also shows a degree of susceptibility, although the morbidity rate of plague is certainly not a high one for this species.

Swine may also contract the disease when exposed to cattle affected with plague, and they may in turn transmit the infection to other pigs and to cattle as well.

Little is known of other host species, but that such may exist is indicated by the fact that the large water leech of the Philippine Islands (*Hiruda boyntoni*) can retain the virus of cattle plague alive and virulent in its body for at least 25 days.

The solipeds, carnivora, man and the laboratory animals in common use are refractive to cattle-plague infection.

Modes and Vehicles of Infection.—Immediate contact with infected cattle is the mode of infection most commonly observed. The feces and the urine appear to be the principal vehicles which convey the virus to other animals, and to a less extent the secretions of the conjunctiva and the nasal, oral, and vaginal mucosae are also apt to play a part.

Recently contaminated food, water, stable utensils, troughs, blankets, floors, highways and railway cars may all be means by which the infection is conveyed. Fresh hides, bones, meat and milk may contain the virus of cattle plague, and serve as vehicles for its transportation. Dogs, cats, poultry, rats, carrion birds and other scavengers cannot always be excluded as potential means of transportation.

Animals infected with cattle plague are always to be regarded as the principal infection sources. There is a general belief that the

period of infectivity of such animals is a relatively short one. In the common run of the cases this period is not more than 2 weeks, and in the more chronic cases certainly not more than a month.

It was shown that plague-infected cattle were capable of transmitting the disease to susceptible animals only during the febrile period of the disease and certainly during the time when the temperature was declining. During convalescence the infectivity progressively declines, but there is evidence that animals during the incubation period may transmit the infection. Recovered cases do not transmit the infection; the existence of more or less permanent virus carriers or spreaders has not been demonstrated.

Cattle or other ruminants which suffer from the disease in a mild and scarcely recognizable form, or those in process of convalescence, are apt to play a prominent part in the transportation and transmission of cattle plague. Such animals are to be especially found among the bovines originating in the permanent centers of infection (cattle of the steppes, Indian cattle).

The principal port of entrance for the virus into the animal body is the alimentary canal, although infection through the respiratory tract is by no means beyond the range of possibility. Certain observations indicate that blood-sucking insects (*Glossina morsitans*) may act as vectors.

The incubation period of cattle plague ranges on the average between 3 and 9 days, but on occasion this space of time may be extended to 17 days.

The danger of invasion of disease-free areas is especially associated with cattle originating in countries where cattle plague is enzootic and which along the highways and byways of commerce may escape the vigilance of sanitary officials.

In regions where cattle plague either exists enzootically as well as in those where the disease has been introduced certain susceptible species may serve as infection reservoirs. Deer, and wild hogs in the Philippine Islands are reputed to play a part in keeping the virus alive and in its transmission to cattle, and, no doubt, the big game of Africa has served and probably may still serve a similar purpose.

Evidence has been submitted that at least for a time the leech (*Hiruda boyntoni*) of the Philippine Islands may constitute an infection reservoir. Water into which the leech had disgorged blood after holding it for a period of 5 days caused cattle plague in a susceptible animal which partook of it. It appears that the leech may be responsible for cattle plague 40 days after imbibing virulent blood, although

it failed to transmit the disease to a susceptible animal by feeding on it.

Factors Favoring Infection.—Many observers are of the opinion that weather and season have a conspicuous influence on the incidence of cattle plague. The hotter and drier the atmosphere, the less is the intensity of the outbreaks and the less marked their spread. It has even been noted that outbreaks were actually aborted as a result of intense heat and severe drouths.

In the tropics, notably the Dutch Indies, the highest mortality is nearly always experienced during the rainy season. Continuous rain anywhere, as well as the cold north winds in China, influence the disease in an unfavorable manner. It seems probable that in addition to a depressing influence by these meterologic factors the unsanitary condition arising from the accumulation of surface water has a part in promoting the infection hazard.

Age seems to have a certain influence on susceptibility; on the whole, young animals are more liable to cattle plague than those of middle age, the very old occupying an intermediary position in this respect. Other factors which seem to increase the natural susceptibility are unsanitary surroundings, improper and insufficient food, severe physical exertion and fatigue. Infection by other diseases, especially the ones caused by hematozooic parasites, must also be regarded as having a predisposing influence.

The predisposing influences mentioned are likely to be more conspicuous in countries where the cattle population is either constantly exposed or where epizootics occur at relatively short intervals. When the disease invades a territory which never was involved in plague outbreaks or which for a long period has been exempt from its ravages, the extreme degree of natural susceptibility is apt to annul all the influences which elsewhere may retard the onslaught of the infection. Cold or hot, wet or dry, the disease progresses regardless of age or other animal qualities.

An abundance of evidence supports the view that cattle populations constantly exposed to the infection or even frequently invaded have developed a certain resistance which reduces morbidity as well as mortality in comparison with animals occupying habitually disease-free territory.

Apparently the breeds of cattle peculiar to regions where the disease is enzootic have by a process of natural selection acquired a relatively high resistance. Or a passive immunity conferred by an immune mother and changed to an active one by exposure during the

period of protection may have become the foundation of their future safety.

However this natural resistance may have been developed, its influence cannot be denied in certain areas. It is a well-established fact that European cattle imported into British India are notoriously susceptible, and that although the bovines of the Himalayan foothills are less liable to cattle plague than the imported ones, they succumb to the infection far more readily than the cattle of the plains or of the low lands. However, this phenomenon is subject to variations in accordance with locality.

Annamite cattle are comparatively but slightly sensitive to the cattle plague virus. In outbreaks of the disease, the mortality varies between 30 to 50 per cent of the animals attached. On the other hand, the improved breeds resulting from crosses with European stock, as well as buffaloes, may die at the rate of 90 per cent of those affected.

In the Dutch Indies the native Sunda breeds and the buffaloes are quite susceptible, the latter probably the most, but the imported Bengal cattle show such a degree of resistance that they are more valuable for that reason, yet the offspring of the latter born in Java is as susceptible as the native breeds.

The relative resistance of the cattle of the Russian steppes cannot be doubted, but this is true only if cattle plague was enzootic in their territory for a long time. Without this, the disease may show its usual malignancy for this type of cattle also.

In the Bulgarian outbreaks, also, it was found that the native gray cattle were less susceptible than the west European breeds. In the former, the mortality rate was 62 per cent; in the latter, it was 95 per cent.

Recovery from the typical disease confers a certain and lasting immunity against subsequent infections. Such animals are often spoken of as having been "salted."

Epizootological Considerations.—From a livestock sanitary point of view nothing is more important than the knowledge that cattle plague is firmly established in many parts of the world and that from there the disease is apt to make disastrous incursions into other territory. No less essential is the knowledge that the cattle in plague-free countries show the highest degree of susceptibility, which makes possible a rapid and deep penetration of the infection if its introduction and progress are not energetically and efficiently opposed.

Ever since cattle plague was known, Asia has been correctly looked

upon as the principal and most permanent focus of infection. Either constantly or intermittently, the disease can be found in the wide stretches of Asiatic Russia, in China, in British India, in Annam, in Tonkin, in the Dutch Indies and in the Philippine Islands. It occurs in Asiatic Turkey, and Japan has been temporarily invaded. No part of the Asiatic continent can be regarded as exempt from the scourge.

Adjacent continents have frequently become involved in the spread of the disease. It has frequently ravaged the cattle of Egypt, and from this focus it spread to central and South Africa. It is present in the Sudan, in Basutoland and in Erythracia, and it probably has found a permanent abode in Abyssinia. It has occurred in the Tschad lake region and spread as far as Senegal and Morocco. Only on account of energetic measures it has disappeared from South Africa since 1899.

All regions in Europe have repeatedly been invaded, but the more efficient livestock sanitary organizations of modern times have apparently been successful in preventing further inroads by the disease. Prior to 1914, Russia had become free from infection, and only in European Turkey did it persist at that time. As a sequel to the catastrophe of 1914–18, disease-free territory was again invaded, and the Balkans, Russia and Poland were infected.

America and Australia have always been exempt with the exception of circumscribed and controlled outbreaks on the latter continent.

In the infected territories the disease shows a certain periodicity in its incidence, although this is by no means a regular one. In the Philippine Islands the severe outbreaks come in cycles of from 8 to 16 years. In India, also, cattle plague varies considerably in severity from year to year. For a period of about 3 years an epizootic gains in intensity, causing great losses, and then for a similar period it abates both in prevalence and in mortality. In the region of Shaowa (China) epizootics occur every 2 years, if not in successive years, and ordinarily they run their course in from 6 to 9 months.

The initial spread of cattle plague in a bovine population is not a rapid one. After the first cases, about 6 or 9 days elapse before new cases develop, but from then on the rate of spread is apt to become progressively more rapid.

Prophylaxis.—Cattle plague disseminated with varying degrees of prevalence throughout the bovine population of a wide area of the world has always been, and is even now, a menace which, if disregarded, may lead to the most costly consequences.

In the plague-free continents and countries with more or less dense cattle populations, always highly susceptible, the exclusion of the disease is one of the principal tasks of the livestock sanitarian, even if the cattle-owning citizenry is no longer aware of its existence or of its tremendous power for harm. But, likewise in the countries in which the disease exists enzootically or which, for various reasons, are intermittently invaded, cattle plague and the heavy losses which it is always certain to cause must be faced with all the means of prevention which can be brought to bear upon the problem.

The measures to be executed, the technique of prophylaxis, must necessarily vary with the circumstances and with the conditions which dominate a given situation. The steps to be taken are determined by a number of factors, among which the following are the more prominent: (1) cattle plague morbidity of the areas concerned, (2) the forces available for livestock sanitary control and the efficiency and legal or executive status of their organization, (3) the intelligence and the sense of civic responsibility of a cattle-growing population, (4) the public financial resources, (5) the presence of such virus reservoirs as susceptible wild animals and (6) the channels of commerce along which the infection may be transported.

In the disease-free countries of central and western Europe, the American and Australian continents and other areas exempt from infection the principal burden of defense consists of absolute exclusion. There the infection must be refused admission; in areas in which cattle plague has obtained a foothold, methods of eradication and the protection of susceptible stock are necessarily the most important. In the absence of an efficient livestock sanitary service, the latter measures must eventually prevail because the disease once introduced will be amenable to such efforts only.

That the success of preventive attempts is to a very large extent dependent on the intelligent co-operation of the people most concerned is quite obvious, and that a lack of public funds immediately available to cope with outbreaks is an almost fatal disadvantage is equally self-evident.

Infection reservoirs in the form of wild animals mitigate severely against successful and rapid eradication and may constitute a problem requiring special efforts for its solution.

The avenues of commerce and the routes followed by cattle in transit have always been strategically important in the struggle against cattle plague and to this day require the closest supervision, especially where propinquity to infected territory increases the hazard.

Sanitary Police Measures.—Well-enforced livestock sanitary measures are the best protection of the cattle population in the plague-free territory. In countries which are amply provided with the output of their own herds, the best defense is the absolute prohibition of the entry of cattle originating in infected countries, of cattle which have passed through such areas in transit or which have been transshipped there and of cattle originating in districts adjacent to plague foci, unless adequate provisions are made for a rigidly supervised quarantine. Even this may prove to be a dangerous concession to commercial requirements.

If, on the other hand, the importation of cattle is necessary on the ground of an inadequate supply of butcher stock or for the purpose of introducing desirable breeding animals, all plague-susceptible animals introduced should be detained for a period of not less than 3 weeks in specially provided quarantine stations. As an additional safety measure, some highly susceptible, native animals should be added to those in segregation and the whole subjected to rigid supervision, of which the daily control of the temperature of all the animals should be a part.

The measures referred to above constitute the most dependable defense against plague that can be devised for those parts of the world which now enjoy freedom from the disease. The rigid supervision of the livestock traffic across their eastern boundaries by the livestock sanitary services of Prussia and by the former Austrian-Hungarian empire and the enforcement of an effective quarantine of imported animals for many years was a barrier which actually protected against plague invasions the whole of central and western Europe, which, for centuries before, had periodically suffered tremendous losses among its bovine population.

In many countries such adequate measures of defense are lacking or on account of local conditions could not be made to operate, and hence the actual outbreaks of cattle plague and its dissemination have periodically to be reckoned with.

To deal with such contingencies by sanitary police measures is often difficult. This is commonly associated with the fact that the infection had already penetrated deeply into the bovine population before its character was definitely established. Early recognition is an essential for effective prophylaxis. Then the first animals involved can be dealt with in a manner to bring about the destruction of all the virus present or to prevent its spread.

Especially in initial outbreaks in clean territory there should be

no backwardness in destroying all animals affected as well as all those which could possibly be regarded as exposed. Such animals should be deeply buried, and all manure, litter and similar materials should be burned. Stables should be disinfected, and no susceptible animals should be permitted on the contaminated premises within 40 days after the last animal died or after the last suspect was destroyed.

All ruminants and swine should be dealt with in a similar manner, and all communication with the premises involved should be confined to what is imperatively necessary. All livestock, except horses, of the surrounding farms should be placed under livestock sanitary supervision and as far as practicable confined to stables and other restricted enclosures. The animals under observation should by preference be divided in small, isolated groups so that, in the event of the disease developing, the group concerned could be promptly destroyed and disposed of in the manner indicated.

Persons who came in contact with diseased cattle, or with infected premises, should not be allowed to proceed without adequate disinfection, and all traffic in feed, hay, straw or stable manure from the infected areas should be suspended for an adequate period.

Only after the initial outbreak has gotten out of hand or in the case of multiple primary outbreaks or if, for lack of livestock sanitary supervision, restrictive measures cannot be taken with any prospect of success, should consideration be given to immunization as a means of protection.

Areas so situated that cattle plague outbreaks may reasonably be expected should, however, always be prepared for such emergencies if preparation is at all possible.

Immunization.—The solid immunity acquired by animals which recover from cattle plague and the introduction of variolization as a means of protection against smallpox in man during the eighteenth century gave rise to the hope that immunity against plague might also be secured by a similar method. Nasal discharge and the lachrymal and conjunctival secretions of sick animals were inserted under the skin in small quantities.

This method was first introduced about the middle of the eighteenth century and was not entirely abandoned until 1874. Especially employed in Russia the virulent inoculations often brought the desired results, and among the cattle of the steppes, losses attributable to this procedure were slight. On the other hand, the application of the method to west European cattle often led to disastrous consequences and eventually brought about its abandonment.

In the already resistant animals of more or less permanently infected regions, no doubt, the insertion of virulent substances under the skin either did no harm or strengthened the fundamental immunity, whereas in the infinitely more susceptible bovines of disease-free areas, it was equivalent to a natural contact infection or even more certain to bring about infection.

The same factor must also be taken in account in the interpretation of the divergent results obtained with later methods. The native resistance of certain bovine populations and the extreme susceptibility of others always exercise a dominant influence on immunization results.

A passive immunity is apt to be conferred to the offspring of immune dams through the agency of the milk. This apparently contains the same specific antibodies as the blood serum, but in a reduced amount. The milk appears to possess a maximum immunizing value about 10 days after a virulent infection. This passive immunity of the calf secured by being nursed by its actively immune dam is only temporary, but under normal conditions it may persist until weaning.

It was experimentally shown to be safe to inject such calves with virulent blood, and it was also shown that the younger the calf the greater was the resistance, the latter depending upon the degree of the mother's immunity.

The method of conferring an active immunity upon passively immune calves has found application only in some isolated instances, but for obvious reasons it can play only a minor part in the control of cattle plague, and these are entirely confined to permanent foci of the disease.

The various attempts to attenuate the virus in the hope of rendering it useful for vaccination purposes have uniformly resulted in failure. The fragility of the virus apparently is too well marked to enable it to survive when exposed to attenuating influences.

Bile Injections.—Prior to 1897 the Boers of South Africa had obtained good results if they injected a quantity of bile taken from an animal in the last stages of the disease. Crude as the method must have seemed, it nevertheless received the attention of Robert Koch, who established the fact that the subcutaneous injection of the bile of a plague-infected animal was actually followed by the development of active immunity.

The *modus operandi* of the bile injections is not known, but presumably the bile contains certain specific substances which exercise an inhibitive action on the propagation of the virus and cause it to be

retained at the point of inoculation, without, however, interfering with its action as an antigen.

The bile used for vaccination is collected from diseased cattle which were killed on the fifth or sixth day of sickness, according to some authors, or between the eighth and tenth day, according to others. If, in actual outbreaks, the date of infection is not known, the beginning of diarrhea or the appearance of nasal discharge may be accepted as a guide.

The bile collected must be free of blood, clear, dark green, and neither too thick nor too watery. The gallbladder of adult cattle affected with plague usually contains about 500 c.c. of bile. It must be used in a fresh condition, and it should be rejected if collected from animals with other transmissible diseases (piroplasmoses).

The dose of the bile, injected subcutaneously, is 10 c.c. The immunity it engenders can be demonstrated about 10 days later. The period of protection extends from 3 to 4 weeks in some cases, from 4 to 5 months in others.

These injections appear to be quite safe, and the vaccination losses which follow their application can usually be attributed to a spontaneous infection already present.

The innocuousness of the bile was strikingly demonstrated by Koch, who added virulent cattle-plague blood to the bile of a plague-infected animal and injected the mixture in several susceptible bovines without transmitting the disease.

The results obtained by means of the bile vaccination method vary. Between 1896 and 1898 more than 2,000,000 head of cattle were treated with it in South Africa with apparent excellent results. In the native Bulgarian cattle the results were less favorable, as it was found that the vaccinated animals might later contract the disease, although in a lighter form and with a considerably reduced mortality.

The addition of glycerin to the bile was proposed by Edington for the purpose of adding an element of safety to the method. Glycerinated bile has not found a wide application, however, and although it is still advocated by some workers, others maintain that the glycerin has an unfavorable influence on the immunizing action of the bile.

A certain disadvantage of this method is that the necessary bile is not always immediately available and cannot be readily procured until an outbreak has gained headway. It requires about a week of sickness before the bile is ready for use and 10 days before the im-

munity is definitely established in the animals injected, whereas the protection which follows is of a relatively short duration.

On the other hand, the method may be applied in outbreaks in remote regions where no other means of protection is available. Its preparation does not require elaborate equipment or a specially trained personnel, and in epizootics it may bring protection at low cost to numerous animals which otherwise might have been lost.

Bile and Virulent Blood.—The transitory immunity secured by the bile vaccination may be materially strengthened by a subsequent injection of virulent blood about 2 weeks later. In regions where periodic outbreaks of cattle plague are to be feared, a series of virulent blood injections may be advisable. The initial injection of 0.2 c.c. of virulent blood will be followed by a mild reaction in some animals and by none in the less susceptible ones. The latter receive at intervals from 8 to 10 days, 1.5 and 10 c.c. of the virulent blood until they react. If there is no appreciable reaction, even after the largest dose, a solid immunity may be presumed to have been established. However, such a method is to be recommended only in an area where the disease is enzootic. In the more highly, susceptible animals of disease-free territory, the method may not only be not entirely safe, but probably impossible as well.

Passive Immunization.—The blood of animals which recovered from cattle plague contains specific antibodies; if the serum or the defibrinated blood of such animals is injected into susceptible ones, the latter may acquire a degree of passive immunity.

The potency of such a serum may be materially strengthened by the process of hyperimmunization, which consists in treating fundamentally immune or "salted" animals with increasing doses of virulent blood. Such a serum preserved by the addition of 0.5 per cent phenol retains its initial immunizing power for considerable periods and hence may be kept in stock for emergencies.

The doses used depend upon the potency of the serum ascertained by previous tests and the type of cattle to be protected. The higher their normal resistance the less serum will be required; hence the doses mentioned in literature show much variation and often range between 25 and 500 c.c.

For the conditions prevailing in India, the doses are calculated in accordance with the normal plague mortality shown in the various districts. The standard dose is the one sufficient to protect the more resistant cattle of the low lands, and this is regarded as ample wher-

ever the average death-rate is less than 50 per cent. If the mortality is higher than 50 but less than 75 per cent, a double standard dose is required. If a mortality between 75 and 85 per cent prevails, 5 times the standard dose is needed; and if the death-rate exceeds 85 per cent, the maximum dose must be given, namely: the one required for the most susceptible highland cattle or 18 times the standard dose ample for the low-land cattle.

On the whole, the passive immunity thus conferred is of but short duration. It cannot be counted on for more than 2 or 3 weeks, although the period of protection apparently may be somewhat prolonged by more massive serum doses.

The serum treatment provides immediate protection and may even save animals in the period of incubation. Its use has a definite place in such outbreaks where, after the destruction of all the affected animals, threatened cattle, as yet not exposed, are to be given immediate protection.

In combination with sanitary police measures, serum treatment was found to be very useful in the beginning of outbreaks. In a series of more than 5,000 animals treated with serum alone, immediate protection was obtained with a loss of less than 1 per cent.

Immunization with Serum and Virus.—The most pronounced disadvantage associated with the use of immune serum alone is the short duration of the protection thus conferred. An active or more or less lasting immunity may be obtained either by injecting the animals protected by the serum with small doses of virulent blood or by exposing them to contact infection during this period of passive immunity.

The former method devised by Kolle and Turner is now more generally used. It is known as the simultaneous method. The required amount of serum is injected into one side of the animal and 1 c.c. of defibrinated virulent blood in the other. In the more susceptible animals a reaction may be the result, and approximately 1 per cent of such animals may succumb as a consequence.

The active immunity established by the simultaneous method affords a protection of not less than 5 months, although instances of a much more enduring protection are not uncommon.

The simultaneous method of immunization is more especially adapted to badly infected districts and particularly in those where sanitary police measures cannot find application.

In former German East Africa the method was applied with very good results; if this was done with promptness the outbreak was

stopped, the subsequent losses being small or ceasing entirely. Similar results were obtained in Egypt.

In order to obviate the possible transmission of trypanosomoses and piroplasmoses by means of the virulent blood, sheep blood may be used for the purpose. This is withdrawn from 3 to 8 days after virulent inoculation. It affords the further advantage that the virus contained in an inoculated sheep may thus be transported for long distances without danger of deterioration.

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CHAPTER XLIII

SWAMP FEVER

Swamp fever or equine infectious anemia is a transmissible, septicemic disease caused by an ultramicroscopic, filterable virus.

It is not possible to ascertain when the disease began to attract attention as a definite entity among equine maladies. It was accurately described for the first time by Lignée, Charlier and Denoc, who, during the forties of the nineteenth century, observed it in the eastern and northeastern departments of France, which for a long time have persisted as important centers of infection.

The origin of swamp fever on the North American continent is equally obscure. It was first reported in 1881 from Manitoba, where it occurred in the Red River Valley and adjacent areas. Apparently the disease was confined to certain districts when it first began to engage the attention of veterinarians and horse owners. There, it occurred enzootically, and although it caused severe losses among the horse population, no regular epizootics have been reported.

After the characteristic features of the disease became better known, it was found to exist in many countries and places. How its dissemination came about is not precisely understood, but, no doubt, the traffic in horse stock had a very active part in it. At this time the disorder is widely distributed. It occurs in Canada, and in this country it has been reported from not less than 20 states. Most European countries have been invaded by it, and it is known to exist also in Morocco, South Africa, Japan and other regions. Military operations have greatly aided in the distribution of equine infectious anemia. Germany especially witnessed a markedly increased incidence of the disorder during and after the war of 1914–18.

In some of its original foci on the North American continent the incidence of swamp fever has conspicuously declined, but on the whole by the invasion of new territory the disease has assumed an economic importance of some magnitude during the last two or three decades.

In its clinical manifestations, swamp fever is characterized by intermittent fever, sluggishness, loss of muscle tone, and a reduction of

body weight. The course of the disease may be acute, sub-acute or chronic. The chronic cases are probably more numerous.

Albuminuria is a common, but by no means constant, phenomenon, and edema of the subcutis is frequently observed during the later stages. In the classic form of the malady which first engaged the attention of observers, anemia was a prominent feature, and this aspect of the disease has remained as the chief characteristic of diagnostic import.

Observation of cases of swamp fever experimentally induced showed that anemia is by no means a constant characteristic of the disorder. Many such cases terminate fatally without a reduction in the number of erythrocytes, and evidence is not lacking that in the naturally infected animals the disease may not be accompanied by anemia. It is this absence of anemia which may render the diagnosis of swamp fever exceedingly difficult and which constitutes an important barrier to a rational prophylaxis.

Most cases succumb in from 1 to 2 months after the characteristic anemia becomes manifest. The mortality of the anemic cases is practically 100 per cent, and even in the acute, non-anemic cases the death-rate is relatively high. It is probable that infected horses never recover, or to state it differently, that they never cease to harbor the virus.

Schalk and Roderick reported a case in which the artificially infected horse survived the initial infection for 14 years without anemia and that at the end of that period, and without any apparent exciting factor, the subject rapidly broke down, showing all the phenomena of a typical field case, including a profound anemia, During the 14-year period the virulence of the blood was fully maintained, as shown by not less than 18 positive inoculations in experimental horses.

Susceptible Species.—Under natural conditions, swamp fever or infectious anemia is seen only in equines. All reports of induced infection in other species must be accepted with caution. It is true that the injection of virulent horse blood into various experimental animals has resulted in illness and febrile reactions, even in death. It has also been shown that the virus may maintain itself intact in such subjects for more or less extended periods. However, unless it could be consistently proved that the virus was able to reproduce itself in a heterologous host species and that in the experimental subjects the disease could be transmitted seriatim inoculation results can be accepted only as manifestations of intoxication by undetermined intoxicants present in a pathologically altered blood.

It is, of course, possible that a case reported by Peters contradicts the views expressed above. It pertained to a veterinarian in direct contact with horses suffering from infectious anemia who, himself, developed a severe anemia. Three experimental horses inoculated with 1 c.c. of the patient's blood developed disease and died. Without further evidence of this nature, one is as yet compelled to accept swamp fever as a purely equine disorder.

The Virus of Swamp Fever.—In 1905, Carré and Vallée showed not only that equine infectious anemia is a transmissible disease, but that its etiologic factor is an ultramicroscopic, filterable virus. They, as well as later investigators, found the causative factor to be constantly present in the blood of infected horses, and hence in all organs provided with a blood supply. The virus is also to be found in the urine, the conjunctival mucus and sometimes in the saliva, as well. Its presence in the milk has been demonstrated. The feces do not contain it unless blood is also present.

The virus of swamp fever shows a relatively marked resistance to external influences. Contained in soil, it maintained its virulence for not less than 6 months, and desiccation at room temperature did not deprive it of its pathogenic qualities after a storage of 7 months. It survived contact with putrefactive material for 10 weeks and for a similar period when contained in urine or feces.

Direct solar radiation at a temperature of 49° C. rendered the previously infective blood inert within a few hours, if exposed in a thin layer. Its resistance to heat is not a marked one, and the virus has been found to be destroyed within a short time by exposure to a temperature of 60° C. On the other hand, it was observed that heating at 56 to 58° C. was not sufficient to kill it within 60 minutes, and that it required an exposure of 2 hours to a temperature of 60 to 61° C. to render it innocuous.

Low temperatures apparently do not affect the virus. Van Es, Harris and Schalk exposed virulent blood to the freezing weather of a rigorous northern climate for 1 month during which the temperature ranged between + 33° F. and — 26° F., and found it to be fully virulent at the termination of this period.

Its resistance to chemical disinfectants is also quite marked. It required an exposure to a 0.5 per cent phenol solution for 4 to 6 weeks before the virus was destroyed, and a similar exposure to a 0.1 per cent solution for 2 months caused only a degree of attenuation. Even contact with a 2 per cent solution of phenol was not sufficient to kill the virus in 24 hours, but when the blood was mixed with equal parts

of a 4 per cent phenol solution, the virulence was destroyed in 1 hour. A 3 per cent solution of a saponified cresol failed to kill the virus in 24 hours.

Modes and Vehicles of Infection.—Aside from the blood and organs and tissues which contain it, the virus of equine infectious anemia exists in various secretions and excretions of infected animals, and it is by these that it is eliminated from the body. Various modes of transmission have been found to be possible, but it is not always clear by what route the healthy animal becomes invaded. Apparently the disorder is not conspicuously contagious, for investigators have, on many occasions, kept affected horses and healthy ones in the most intimate contact with one another without such a close cohabitation resulting in the transmission of the malady.

On the other hand, experimental transmission is readily accomplished by the subcutaneous or intravenous inoculation of very small amounts of virulent blood or serum. Even a mere puncture by a needle dipped in the blood of a swamp-fever horse has resulted in the infection of a healthy subject.

It was shown in many experiments that infection *per os* can be readily accomplished. In the course of investigations by the North Dakota Experiment Station, the oral administration of capsules filled with virulent blood resulted in producing the disease in experimental subjects. Urine introduced by the same route also induced a similar result, as had already been shown to be possible by Carré and Vallée in the course of their earlier studies. Apparently the induction of disease by means of urine succeeds best when relatively large quantities are used; in many instances of successful transmission in this manner the period of incubation was longer than after the use of blood for the same purpose.

Scott states that swamp fever may be transmitted by flushing the nasal cavities of a healthy horse with the nasal washings of an infected subject.

The earlier investigators concluded that contaminated food and drinking water served as the principal vehicles in the transmission of the virus, and as its possibility is sustained by experimental evidence this mode of infection cannot readily be left out of consideration.

Later investigations by a Japanese commission, by the Wyoming Experiment Station, and by others, showed the possibility of transmission by insect carriers, such as *Anopheles, Stomoxys* and *Tabanus.* These results were sustained by Stadler, who transmitted the disease

by an inoculation of an extract prepared from blood of sucking flies caught upon horses suffering from the malady.

Scott believes that he has rendered conclusive proof that in Wyoming *Stomoxys calcitrans* and *Tabanus septentrionalis* are particularly capable of serving as vectors of the infection. It now seems more than probable that in most instances natural infection comes about by means of biting, flying insects and that the latter act in a purely mechanical manner and not by having a part as intermediary hosts.

Infection of the fetus *in utero* has been observed, and transmission by copulation has been suspected. Sucking colts apparently have been observed to contract the disease through the agency of the milk.

The use of soiled or inadequately sterilized surgical instruments and appliances has been pointed out as a means of transmission. The dissemination of swamp fever in Europe after the war of 1914–18 has in part been attributed to the use of immune sera in the control of other equine diseases.

The period of incubation ranges between 5 and 57 days with an average duration of 5 to 10 days. In most of the experimental cases described by Van Es, Harris and Schalk the incubation periods fluctuated between 6 and 21 days.

The disease is commonly introduced into healthy stables by means of infected horses, among which the unsuspected, apparently normal infection carriers seem to play a most prominent part.

Factors Favoring Infection.—As the earlier descriptions of the disease on the North American continent came from certain regions where the land is level and poorly drained, the impression got abroad that equine infectious anemia was particularly associated with swampy regions. This fact gave the disorder the popular name by which it is best known. With the acquisition of additional knowledge of the malady it soon became apparent that the topography of the areas involved exercised little or no influence on its incidence.

Whether or not season *per se* has a direct bearing on incidence has not been definitely ascertained. Whatever seasonal factor may be in operation is probably more potent in connection with insect vectors than with the virus or with the susceptibility of the specific host species. Doubtless, transmission comes about more readily during the warmer season, but in a malady so apt to assume a latent form, it is practically impossible to obtain precise data relating to this part of the problem.

No doubt, any influence of a character prejudicial to animal well-being may, as in other diseases, tend to increase the morbidity of swamp fever also, but there is no good evidence which shows adverse living conditions as being a factor either in susceptibility or in a more ready transmission. Age apparently exercises but little influence, and all age groups are equally susceptible.

Prophylaxis.—As long as there is no specific method of diagnosis suitable for ready application, the prophylaxis of swamp fever will remain exceedingly difficult. With such a method available, the non-clinical virus carriers could be eliminated, but without this, progress against the malady will be slow and efforts at prevention often disappointing.

Oppermann and Lauterbach devised a diagnostic test based upon a hemagglutinin reaction. They found that in the serum of swamp-fever horses there occur certain agglutinins able to induce clumping of the erythrocytes of rabbits injected with the specific virus. Whether or not the reaction is a strictly specific one is a matter of doubt, and this doubt is certainly not diminished by their statement that a similar reaction also takes place with the blood cells of non-injected rabbits which were depleted by frequent bleedings. Whatever future investigations may bring to light regarding the value of the hemagglutinin test for swamp fever, there is, as yet, no warrant for destroying reacting horses in a general application of radical measures against the disease.

Certain preventive measures, however, cannot be denied a place in prophylaxis. Prudence in the purchase of new horse stock should always be exercised. Horses from infected districts should always be rejected and if purchased they should be subjected to a careful control of their body temperature. To supplement this with frequent examinations of the urine for the presence of albumin should be looked upon as an additional safeguard.

The movement of horses from districts where the disease is enzootic should be suspended if at all possible. Horses originating from infected areas should be kept in isolation until their freedom of infection can be definitely established.

Pastures in which cases of swamp fever frequently occur should be closed to horses for not less than a year and if possible for even a longer period. In local or stable outbreaks, the anemic cases should be destroyed, especially during the fly season. Temperature measurements and urine tests should be frequently applied to all other horses of the establishment in an effort to identify possible virus

carriers. If such are found, they should be promptly segregated or destroyed.

The water supply should be carefully supervised and all surface water accumulations either removed by a suitable method of drainage or by the exclusion of the animals by means of a fence. Wherever control measures against insect pests are possible or applicable this means of prevention should not be neglected.

Immunity against swamp fever does not develop, and hence control by immunization is as yet out of the question.

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CHAPTER XLIV

BLUETONGUE

BLUETONGUE, or catarrhal fever, is a specific, transmissible disease of sheep caused by an ultramicroscopic virus and characterized by certain lesions of the mucosa of the mouth, the upper air passages and the intestines, sometimes accompanied by inflammation of the claws.

The disease is peculiar to South Africa where it is widely distributed, in Rhodesia as well as in the Union.

Bluetongue was probably observed in the Cape Colony quite early after its settlement, but it was not until the beginning of the present century that the studies of Spreuell and Theiler revealed its specific character.

Clinically the disorder manifests itself by a marked initial rise of the body temperature (104 to 107° F.), followed by more definite symptoms about a week after its onset. At that time the affected animals become gaunt, and a bluish discoloration of the oral mucous membrane is apparent.

The sheep involved lick their lips, and there may be frothing from the mouth. The swelling of its mucosa gradually increases, and this may extend to the tissues of the submaxillary space. Damage to the mucous membrane may render mastication difficult and painful. Diarrhea is observed in the later phases of the malady.

With the involvement of the feet, the animals become lame and are apt to assume a posture resembling that of a foundered horse. Toward the last a marked emaciation may be observed, and in the nonfatal cases, the period of convalescence is commonly a prolonged one. Bluetongue usually runs its course in about 3 weeks.

The death-rate of bluetongue varies. During certain seasons mortality may be rather low in a given herd, whereas at other times, about one-third of the effectives may succumb, the case mortality even exceeding 50 per cent.

With the exception of the lesions of the mouth, the after-death appearances in bluetongue cases are not very characteristic. There usually is a marked waste of flesh and a gastro-enteritis may be noted.

In such cases, the mesenteric lymp nodes are enlarged and hyperemic. Liver and kidneys are congested, and the coverings of the heart may show ecchymoses.

The high death-rate, and the loss of flesh and fleece of the animals that do recover, combine to make bluetongue a disease of considerable economic importance.

Susceptible Species.—Sheep are the only animals liable to spontaneous bluetongue. Attempts to transmit the disease to horses, cattle, goats, dogs and rabbits resulted in failure. In certain experimental efforts, the virus has been successfully inoculated into calves and goats, and although these animals failed to sicken, their blood, after a time, was shown to be virulent to sheep.

The Virus of Bluetongue.—The virus of bluetongue is ultramicroscopic; filtration experiments with virulent blood serum diluted with physiologic salt solution showed that it is not retained by a Berkefeld filter. It is present in the blood and various organs of affected sheep.

Bluetongue virus manifests considerable resistance to external influences. Spreull reports that the blood of sheep affected with bluetongue, although subject to a degree of attenuation at room temperature, retained its virulence for a very long time. Several of his virus specimens preserved for more than 400 days were still capable to cause a typical bluetongue and even the death of the experimental animals. In his experience, 693 days was the longest storage period after which the virus gave rise to fatal bluetongue.

The virus is not destroyed by putrefaction, and desiccation does not always result in its destruction, although such a treatment may impair its virulence.

Bluetongue virus can be preserved for as long as 2 years in a mixture composed of 1000 parts of virulent blood, 1000 parts of glycerin, 1000 parts of water and 1 part of phenol.

Modes and Vehicles of Infection.—Bluetongue can be readily transmitted to susceptible animals by means of subcutaneous, intravenous, intratracheal or intraperitoneal inoculations of the blood or the blood serum of sheep actually suffering from the malady. Only very small doses of the inoculum are required to bring about a positive infection.

Most authors have expressed the opinion that the blood of sheep which recovered from bluetongue is no longer virulent, and that the part played by virus carriers apparently is no factor in the problem. Relatively soon after the febrile stage of the disease is passed, the

virus disappears from the blood. This, however, may not be a constant feature, as more recently du Toit discovered that the virus may persist in the blood of recovered sheep for a period of about 4 months. He found that during this period there may be times when the presence of the virus cannot be demonstrated.

The malady cannot be transmitted by direct contact. A substantial volume of epizootologic evidence strongly indicates that a nocturnal, flying, blood-sucking insect is the vehicle by which the infection is passed from animal to animal. Nothing of a precise nature is known about the insects which have a part in the dissemination of bluetongue, although mosquitoes are strongly suspected in this connection.

According to Spreull, the period of incubation extends from 2 to 5 days, 3-day periods are the most common, but those of 2 and 4 days' duration are frequently observed, 5-day periods being relatively rare.

Factors Favoring Infection.—The incidence of bluetongue is influenced by a number of factors. Important among these is the one exercised by locality. Moist areas, such as bottom lands and swampy pastures, are particularly favorable to morbidity. The disease is apt to occur at most altitudes, and apparently the absolute elevation above sea-level is less of a factor than the relative elevation of a given area as compared with that of the surrounding country.

The seasonal influence is a marked one in bluetongue epizootology. The disorder, although varying in its incidence from year to year, is most apt to be prevalent during wet seasons and especially so in the course of the summer months (January to April). Bluetongue cases are rarely seen in winter.

Bluetongue is essentially a pasture disease and is most commonly contracted during the night, the early morning hours and the later part of the evening. After sunrise, the infection hazard incurred by sheep in the open is materially reduced.

The influence of age is apparent in bluetongue morbidity. It shows a higher rate in young than in old animals. It is highest in sheep from 1 to 2 years old, whilst sucking lambs are, to a large extent, exempt from the infection.

The more refined breeds, such as the Merino, show the highest degree of susceptibility. The so-called Persian or fat-tail sheep are more resistant, and animals bred in bluetongue territory are more refractive to the infection than those originating in disease-free territory.

Sheep which recover from the disease acquire an immunity, which,

though not an absolute one, is quite sufficient to reduce losses among such animals to a minimum.

Recently shorn sheep are apparently more liable to contract the disease than those in full fleece.

Prophylaxis.—Certain details of flock management are of value in prophylaxis. The removal of the sheep from bluetongue territory during the summer months to dry pastures at a higher elevation is, no doubt, useful as a preventive measure. Even an outbreak in progress can often be checked by this means.

Sheltering the sheep in stables or other types of enclosures overnight has a definite value in prophylaxis. The use of dipping fluids containing tar tends to check the progress of the disease in outbreaks. Such disinfestants apparently have a repellent influence on the probable insect vectors of the virus.

Recognition of the fact that sheep with a heavy fleece are apparently less liable to contract bluetongue than those which were recently shorn is responsible for the practice of postponing shearing operations when an impending infection hazard has to be faced.

Immunization.—Any one of these measures has a certain deterrent influence on the spread of the malady, but a maximum degree of protection can be secured only by protective inoculation.

The immunity acquired after recovery from the disease encouraged experimental attempts to secure similar results by artificial procedure. As early as 1901, Spreull discovered that the blood serum of hyperimmunized animals when injected into susceptible ones exercised a very potent protective influence. Some years later (1905) this investigator recommended the simultaneous injection of serum (4 c.c.) and virus (2 c.c.). His method proved to be quite effective, but had the disadvantage of a relatively high cost arising from the necessary process of hyperimmunization.

Spreull's method was largely superseded by the one devised by Theiler which has since established itself as the most widely used means of conferring artificial immunity.

Theiler (1908) discovered that a series of several passages of bluetongue virus caused the latter to become attenuated to such a degree that it could be safely used as a vaccine. The active immunity thus engendered endures for about a year.

Since the introduction of Theiler's vaccine, not less than 25 million doses have been distributed with results described by du Toit as "very good indeed." The latter, after a more recent investigation, was led to conclude that an annual vaccination is sufficient to protect

sheep against bluetongue. The vaccination should always be undertaken well in advance of the bluetongue season, the most favorable time being the spring of the year (September to November).

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CHAPTER XLV

HEARTWATER

THE name heartwater is applied to a specific, acute, febrile disease peculiar to certain domesticated ruminants. The disorder has its principal area of distribution in South Africa where it coincides with that of the bont tick (*Amblyomma hebraeum*). These areas are more or less restricted and include certain coastal regions, the brush veld of the Transvaal, Bechuanaland, parts of Zululand, the eastern parts of the Cape Colony and the Transkeian district.

The appearance of heartwater was synchronous with that of the bont tick, which was first observed in 1840 by a Mr. William Bowker on a cow originating in Zululand. Since that time the malady has frequently proved itself to be a real scourge. According to Spreull, the systematic practice of dipping cattle during the last decades has resulted in a marked reduction in heartwater morbidity.

The disease first manifests itself by a high body temperature (104 to 108° F.), although in some instances its presence is first disclosed by the sudden, unexpected death of some of the animals (sheep, goats) concerned.

One or two days after the initial fever, the affected animals appear dull, separate themselves from the herd, cease to ruminate and begin to show evidence of nervous disturbance. They shake their heads, present spasmodic masticatory movements, convulsions and distress expressed by excitability and bleating.

Paralysis of the hind quarters is sometimes observed, and in some animals galloping motions of the legs may be seen when the standing posture can no longer be maintained.

In the more slowly progressing forms of the disorder, occasionally observed in sheep, the wool becomes readily detached. Most cases of heartwater run their course in 2 to 6 days.

The death-rate of heartwater is a high one. A case mortality of 70 to 80 per cent must be reckoned with; in the most susceptible breeds it may amount to 90 per cent or more. Spreull observed that

susceptible small stock brought onto infested pasturage die off very rapidly. Among Merino sheep, losses of 50 per cent within a few months have been known, and in young Angora goats the deaths may reach 80 per cent.

The name "heartwater" reflects the more striking and characteristic of the lesions found in animals dead with the disease, namely, the accumulation of a straw-colored, serous fluid in the pleural and pericardial sacs. Other lesions are less pathognomonic. Among them may be observed: gastro-intestinal congestion or ecchymoses, endocardial petechia, pulmonary edema and congestion of the brain and its meninges. Spleen and liver are often slightly enlarged, and the kidneys are hyperemic.

Susceptible Species.—Cattle, sheep and goats are the only domestic animals susceptible to heartwater. The disease has occasionally been seen in the springbok, one of the local wild antelopes. The resistance of the horse can be experimentally established.

The virus of heartwater is present in the blood of affected animals. It has commonly been accepted to be a filterable, ultramicroscopic organism, although as early as 1904 some doubt regarding these characteristics was expressed by Theiler. Encouraged by the latter, Cowdry, in 1925, undertook a further study of the subject and was able to demonstrate the presence of a Rickettsia in animals infected with heartwater. Cowdry submitted evidence strongly pointing to an etiologic relationship of this organism to this disease, and proposed the name *Rickettsia ruminantium* for it. The micro-organism is most easily detected in the endothelial cells of the renal glomeruli and the small capillaries of the cerebral cortex. Cowdry's observations have since been confirmed by Daubney.

As the virus occurs in the blood it is especially marked by its fragile character. The blood always loses its virulence within 3 days and most frequently even within 48 or 24 hours. It is rapidly destroyed by drying.

Modes and Vehicles of Infection.—Heartwater is not a contagious malady. Experimentally it can be readily transmitted to a susceptible animal by subcutaneous or intravenous inoculations of fresh blood, spleen pulp or the cerebrospinal and thoracic fluids collected from an affected or convalescent animal. On the other hand, animals which have completely recovered from the disease no longer carry the virus in their blood.

In nature the disease is transmitted only by its vector, the bont tick (*Amblyomma hebraeum*). In order to do so, the tick, either

as larva or as nymph, must have previously fed on a diseased or convalescent animal.

The virus taken up by the tick is not passed on by the egg, but is either taken up by the larva and transmitted to the warm-blooded host by the nymph or is acquired by the nymph and passed on to the imago.

Thus, transmission is brought about either by the nymph or by the adult tick. The latter may serve as a vector even after having passed through its nymphal phase on a host not susceptible to heartwater. Such ticks do not "clean" themselves. One tick has been found to be capable of transmitting the disease. Incubation periods extend from 5 to 18 days, usually ranging between 8 and 10 days.

Factors Favoring Infection.—It is obvious that specific susceptibility exercises an influence on morbidity by determining the number of animals apt to become involved as well as the volume of virus present in a given locality.

Most susceptible to heartwater are goats and sheep. Cattle also contract the malady, but are less susceptible and show a more marked tendency to recovery after an attack. Within the species concerned, the specific susceptibility is subject to racial influences. All breeds of goats and sheep readily contract the malady, but the greater mortality is observed among the more improved and refined ones. Thus Angora goats and Merino sheep are exceedingly susceptible and vulnerable to the infection. The common goats of the natives and the fat-tailed sheep of the country are somewhat refractive and show a lower death-rate.

The so-called Persian sheep of South Africa show a peculiar resistance. Although they readily contract the disease, showing a distinct febrile reaction, they rarely succumb to the disorder. Crosses between the so-called Persian sheep and the other breeds show resistance or susceptibility in accordance with the blood that predominates.

Heartwater losses are greatest among animals recently imported into the country, as well as among the ones born in parts of Africa where the disease is not enzootically established. On the other hand, cattle reared in heartwater territory may develop a marked degree of resistance. Young animals are less resistant than older ones.

Immunity follows recovery from the disease. Without being of an absolute character, it tends to remain intact for about 18 months.

Locality is a factor quite essential to heartwater morbidity, owing to the ecologic requirements of the vector tick, which thrives only in

warm, moist areas. For the same reason, a seasonal influence is apparent. The disease shows a greater incidence and a more marked virulence in summer than in winter.

Prophylaxis.—The prevention of heartwater, its eradication even, can be attempted only by the systematic destruction of the ticks which transmit the disease (see chapter XIII), by the starvation and dipping methods. In the former, all animals carrying ticks must be excluded for a period of 20 months or more in order to make certain that both nymphs and imagoes have definitely succumbed.

In the eradication by dipping, the treatment can be confined to the cattle alone. The frequent dipping of sheep is not a practicable procedure, and the cattle serve the purpose of gathering the ticks and of transporting them to the dipping vat where they can be adequately disposed of.

The practice of the systematic dipping of livestock as a means of prevention of other tick-borne diseases has resulted also in the disappearance of heartwater from areas in which the disease once caused sheep farming to be discontinued. In areas where the malady is still apt to occur, tick-infested, moist, low, warm places should be avoided as pasturing ground for susceptible animals. When an outbreak once declares itself, no time should be lost in transferring the herds concerned to higher ground.

No satisfactory method of immunization against heartwater has as yet become available.

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CHAPTER XLVI

RABIES

General Considerations.—Rabies is an acute, infectious disease to which most species of warm-blooded animals are susceptible. It is a disease of the central nervous system, and as such it manifests itself by psychic disturbances, increased excitability and paralytic phenomena during the various stages of its course. Rabies is practically uniformly fatal for the affected animals.

The terrible suffering which it inflicts on its human victims, as well as the inevitable fatal termination, have from early times vouchsafed for the disease a wide, popular interest. Already mentioned in ancient literature, its dramatic appeal has been sustained through the ages. Its nature and cause have been subjects for speculation and disputation since antiquity, and the most astonishing and absurd theories have been tenaciously maintained and defended even to modern times. Especially did the therapy and prophylaxis of the disease mobilize the minds of physicians and priests, of magicians and charlatans. Nothing seemed too cruel, too revolting or too silly to be inflicted on the unfortunate victims of the disease. Fire and water, cock's brains and dog's livers, worship at St. Hubert's shrine, even the "adjustments" of the legalized quackery of our present day have all been brought to bear on this ancient problem, either with the noblest of intentions or merely in a quest for pelf.

The application of experimental inquiry to the rabies problem during the greater part of the nineteenth century, which culminated in the discoveries of Pasteur, ushered in a new period. The post-infection immunization discovered by the master robbed the disease of its terrors for civilized man. Pasteur's achievement was supplemented by the discovery of Negri, who made possible a rapid diagnosis of the disease in the biting animal.

From the standpoint of livestock sanitation and the public health, rabies continues to be a subject of paramount interest in all countries, and from time to time the disease demands the most serious consideration.

Host Species.—Among the domestic animals, dogs and cats furnish the greatest number of rabies cases. Horses, cattle, camels frequently become affected, and sheep, goats and swine commonly figure in outbreaks of the disease. Man himself is readily infected; domesticated birds, although susceptible to a degree, but rarely contract the disease in the natural manner.

Among the wild animals, the disease is especially frequent in wolves, foxes, jackals and hyenas. Outbreaks among deer and antelopes have been observed, and smaller mammals, such as skunks, rats and mice, also show a high degree of susceptibility.

It is possible that such small animals may serve as infection reservoirs in certain regions. That they play a very conspicuous part in the maintenance of infection centers is, however, somewhat denied by the readiness by which the disease may be eradicated by appropriate sanitary police measures, as was shown, for instance, by the experience in England. On the other hand, in wild regions where wolves, coyotes and other carnivora abound, these animals constitute a formidable infection source which is apt to establish permanent foci of the disease.

The Virus.—The causative agent of rabies is as yet unknown, and although there is warrant for classifying it with the ultramicroscopic viruses, the knowledge of its nature has not been materially increased since the days of Pasteur. Its presence can be shown only by inoculation experiments, and thus it was found that it is constantly contained in the central nervous organs of affected animals and to a less extent in the peripheral nerves.

It can be shown to exist also in the salivary glands and the saliva, the latter serving as its vehicle in the transmission of the disease. The virus of rabies has also been shown to exist in the pancreas, the lachrymal glands, the mammae and the milk, the aqueous humor, in the kidneys and adrenals, and in the testicles. It has occasionally been found in the blood.

So far as is now known, it is to be found only in affected animals, and apparently there are no permanent virus carriers.

Contained in the central nervous organs the virus is quite resistant to external influences, the action of the latter being largely subject to the degree of trituration to which the virulent material may have been subjected. It is damaged by light,. by drying and by heat, but it is not readily affected by the action of putrefaction. Exposure to low temperatures does not appear to impair its viru-

lence, which may be conserved for considerable periods when the virulent organs are preserved in glycerin.

The various disinfectants destroy the virus quite readily, the thoroughness and speed of their action being materially influenced by the size of the organ particles in which it may be contained. The finer the trituration of the material, the more readily the destruction of the virus takes place.

Modes and Vehicles of Infection.—The transmission of rabies can be brought about only by inoculation and by the deposit of virulent material in a wound or abrasion of the skin, or a mucous membrane.

In a marked preponderance of cases, the bite of a rabid animal constitutes the natural mode of infection. In this, the dog or other members of the canine family play a most conspicuous part. These animals constitute the most important infection reservoir. In the more settled and civilized countries, about 93 per cent of the infective bites were inflicted by dogs and approximately 5 per cent by cats. In such countries as Russia, Rumania, and in some of the western states of this country, wolves, foxes and coyotes also are responsible for a considerable proportion of the rabies cases in other animals.

Only animals actually sick with rabies, or in the period of incubation, can transmit the disease, and there is no evidence that bites by animals which themselves remained in an enduring state of health have ever been followed by the development of rabies in bitten persons or animals.

On the other hand, infection may be admitted through recent abrasions of any kind, when they become soiled by virulent material (saliva of rabid animals), so that, for practical purposes, the scratches made by a rabid cat must be given the same consideration as a bite. Even the intact mucosa cannot be entirely depended on as an absolute barrier against the virus.

Attention must also be called to the infection hazard incurred by veterinarians, physicians and laboratory workers during autopsies, when they accidentally wound themselves on projecting splinters of bone or by means of the cutting instruments used in their work.

Hygienically important is the incubation period of the disease. This is subject to great variation as to length of time, but the disease, as a rule, is characterized by a long incubation. Apparently the virus reaches the central nervous organs by way of the nerves, and the speed by which it travels, the distance to be covered as well

as its volume are the factors which help to determine the length of the incubation period.

In man, the shortest period of incubation is about 12 days, but the greater number of the cases sicken sometimes during the second month after the bite was received. Extraordinarily long incubation periods have been recorded. Incubations of a year or even more have been observed but must be regarded as extremely rare.

In the dog, the most frequent incubation periods range between the twentieth and fiftieth day, rarely less than 15 or more than 80 days. The same periods have also been established for the cat.

In the horse, the period extends for the majority of the cases from the fifteenth to the sixtieth day, but in about 15 per cent of the cases it exceeds 3 months.

In cattle, most cases declare themselves from the first to the third months after the infective bite; incubation periods of more than 100 days are rare in this species.

Sheep and goats show an average incubation of from 15 to 30 days, but in about 10 per cent of the cases, it may be prolonged to 60 or 70 days.

In swine, the incubation requires from 15 to 60 days, but in approximately 11 per cent of the cases the first symptoms appear after the termination of that period.

In the rare cases of spontaneous rabies of fowls the incubation period is not less than 6 weeks, but may be prolonged even to a year.

Factors Favoring Infection.—Although the disease is apparently more common in the temperate climate zones than in the tropics, there is no statistical evidence which would indicate that the season exercises an influence on the morbidity rate. The popular notion that rabies is peculiarly a hot-weather disease cannot be sustained; cases are apt to occur throughout the entire year. On the other hand, it is probable that periods of rut may be marked by an increased incidence of the disease inasmuch as during such times the congregation of dogs, often in fierce combat, is bound to promote the opportunity for infection.

The morbidity of rabies is influenced by the density of the canine population as well as by the presence of infection reservoirs associated with such wild animals as wolves, coyotes and foxes. The factor which, above all, favors the occurrence of the disease is a great number of homeless, tramp dogs.

Indications show that young animals become infected more readily

than old ones, but probably the fact is more associated with a lack of reserve and a greater combativeness of the younger animals, at least so far as dogs are concerned. That children become more frequently affected than adults is probably not due to a mere age factor, and may be attributed partly to their lack of caution but chiefly to the fact that they are more severely bitten, and further that they are more often bitten on the face.

Even though all wounds inflicted by rabid animals are by no means followed by positive infection, they must, nevertheless, be regarded with apprehension. In the lower animals it is imperative to regard the bitten animal as a potential factor in the further spread of the disease.

The locality of the bite, however, seems to influence the infection chances in a substantial manner. The richer the bitten part is in nerve structures, the more dangerous the bite; and the nearer the bite to the central nervous organs, the greater the chances that rabies will follow.

The bite in a part not covered by fleece, hair coat or garments is always more dangerous than if the penetrated tooth may have been wiped clean of virus by passing through the substances mentioned. Deep wounds are particularly to be feared as ports of entrance for the virus, and the chances of positive infection are always favored by a multiplicity of bites.

Epizootologic Factors.—With the exception of Australia, where it has thus far not occurred, rabies is distributed over the entire world, and in particular the parts which lie within the temperate zones. If the disease is extinct in such countries as the Scandinavian and British kingdoms, the happy situation is entirely due to the adequate sanitary police measures which were brought to bear on the problem.

With the modern rapid means of communication it may be maintained that without constant vigilance no inhabited part of the world, not even the hitherto infection-free continent of Australia, would escape outbreaks of the disease.

In past times the disease has frequently assumed the form of extensive epizootics. Even now, although they no longer occur in the more civilized countries, many of the latter still register conspicuous losses of livestock caused by rabies.

Sanitary police measures, difficult as their rational enforcement often proves to be, nevertheless, constitute the sole reason for the disappearance of the formidable outbreaks of the past.

The many localized outbreaks common in most countries continue to engage the attention of livestock sanitary officers the world over, and there is a probability that this will continue to be the case for a long time.

Prophylaxis.—The prophylaxis of rabies in most organized countries is a simple procedure so long as the steps to be taken are not restricted by an obstructive public opinion.

The virus source practically always lies within the infected dog or other animal. The virus does not persist in extracorporeal situations in a given environment, nor is it harbored by arthropodal carriers. Only in the areas in which wild, living carnivora still abound may an adequate prevention of the disease be rendered impossible or at least extremely difficult. To what extent other infection reservoirs may interfere with eradication is difficult to determine, but the success achieved in certain countries does not indicate that they constitute a reason for discouragement.

The measures to be taken must include the sanitary management and control of the canine population under normal circumstances, its control in outbreaks and the care of persons as well as the disposal of animals which may have been bitten by rabid animals. The first line of defense against rabies is associated with the first measure; the second one with the last two.

Except in those countries which are free of rabies and which are adequately protected against the introduction of the disease from without, the probability of outbreaks must always be faced. In all other parts of the civilized world, the control of the canine population should not be neglected, however difficult this may be during the intervals when the disease is not observed.

Reduction of Dog Population.—In actual sanitary practice a reduction of the canine population can be applied only to the dogs without a declared master or owner. Ownerless dogs in many sections constitute a considerable proportion of the total number, and it is this class of canines which form the most formidable source of rabies infection.

The habits of such dogs render them more liable to exposure, increase their contact hazards, render them more formidable as spreaders and make the prompt recognition of the disease most difficult. Both under normal conditions as well as under those imposed by the actual presence of the disease, the elimination of this portion of the dog population is always a most important factor in the prevention and control of the disease.

Dog Registration and Dog Tax.—As a means of elimination of the canine surplus, the imposition of a tax or license fee is very efficient provided such a measure is rigidly enforced. The dogs on which a tax was paid must be provided with a collar on which a metal tag, marked by a serial number, is attached, as a means of identification and as visible evidence that the dog has an owner or master. A register of all dogs should be kept, indicating the names and addresses of their owners. A legal provision imposing on the owners a definite responsibility for any damage which their animals may inflict will have a further wholesome effect in keeping the canine population within certain numerical bounds.

Owners should be given a certain length of time after which the tax must be paid and the dogs provided with their identification mark. After the expiration of this period, all untaxed dogs should be subject to capture and impounding. The impounded canines should be held subject to redemption for a period, and all unredeemed dogs should be humanely destroyed.

If the registration of dogs is rigidly enforced, a reduction in the number of tramp dogs can be readily accomplished, but altogether too often such measures are extremely unpopular with certain classes of people, and hence their enforcement is commonly very lax and thus fails in its purpose. Even a very low tax does not always improve the public attitude, and nothing short of a catastrophe brought about by the disease will arouse dog owners of a certain type to their civic obligation or the police authorities to a more rigid discharge of their duties.

In countries where dog-tax provisions could be adequately enforced, they have always been followed by a corresponding reduction in the incidence of disease.

General Vaccination.—The idea of coping with the rabies problem by means of artificial immunization is not less than a century old and since its conception has been repeatedly advanced as a possible factor in its solution. The remarkable achievements of Pasteur brought hope that vaccination might be utilized as a means of control if not of eradication.

Since Pasteur's time a considerable amount of effort has been devoted to devising an immunization method against rabies in dogs. The results were not satisfactory, largely because the conditions which would have to be met were extremely difficult of fulfilment. To prevent the disease in an infected person by post-infection vaccination and to create a pre-infection resistance in an entire canine population

or in a considerable portion thereof are indeed tasks which can scarcely be compared.

A method applicable in the general vaccination of dogs must be absolutely free of the danger of causing vaccination rabies, must be simple in its application and must be followed by an immunity of considerable duration. Even if a method by which all these conditions could be met were discovered, the practical application would still remain a most difficult task. In view of the almost insurmountable difficulties which are encountered in the enforcement of a dog-tax provision in the number of tramp dogs and the need of repeating the vaccination at least once a year, a general compulsory vaccination of a canine population does not appear very promising as a means of solving the problem.

On theoretic grounds and on experimental evidence, at least, the possibility of conferring immunity on dogs must be admitted, but whatever can be achieved in that direction will probably remain confined to selected groups of dogs, the owners of which desire protection for their animals.

Owing to the many difficulties associated with the practical application of dog vaccination, the use of antiserum, sero-vaccination, the methods of Pasteur, Högyes, Puntoni, Fermi, Remlinger, Schnürer, Mieszner and others have thus far failed to gain the favor of sanitary authorities as bases for a specific prophylaxis.

It is yet difficult to arrive at a definite conclusion with regard to the method designed by Umeno and Doi. This method consists of a single injection of a fixed virus, suspended for a given time in a mixture of glycerin and phenol solution. Generally known as the Japanese method, it has shown some favorable results when experimentally applied, but in view of certain observations made in tests by the U. S. Bureau of Animal Industry, it does not appear that this means of defense against rabies can as yet be recommended as a base for the general compulsory vaccination of dogs.

In Japan as well as elsewhere, a great number of dogs were vaccinated in accordance with Umeno and Doi's method with apparent good results, but owing to the fact that it is impossible to determine the degree of exposure to infection in the vaccinated and the unvaccinated groups of dogs, the value of such data is seriously impaired.

The consideration of the data pertaining to this method, so far as they originate from disinterested sources, is fully justified, and there is ample warrant that further studies be made in order fully to determine its value and possibilities. On the other hand, its manda-

tory application by legislative enactment must be regarded as premature at this time.

Although hope may be kept alive that some immunizing method may eventually become a factor in the general pre-infection prophylaxis of rabies, sound and adequately enforced sanitary police measures remain as the first line of defense against the occurrence of disastrous outbreaks.

Destruction of Wild Carnivora.—The destruction of predatory animals, especially those belonging to the canine family, is a measure without which the control of rabies in certain countries would be illusory. Wolves, coyotes, foxes, jackals and similar animals may furnish a permanent infection reservoir, and the more abundant such animals are, the more profuse will be this source of mischief.

Various methods have been applied in attempts to cope with the problem. They range in character from drives, locally organized, to systematic efforts undertaken with public financial support. This commonly involves the payment of bounties on animals captured. As a rule, the results of such a method are problematic. This is largely due to the fact that the most effective means of destruction, poison, is not used by the bounty hunter, because the method often precludes the recovery of the animal killed.

Another disadvantage peculiar to the bounty system is to be found in the fact that hunters may become more interested in preserving the predatory animals, as a source of income, than in their elimination. With that object in view, female animals are released from traps in order that the supply may not diminish; occasionally one hears of the propagation of coyotes in fenced areas.

In the experience of the Rabies Commission of the State of Nevada, the regularly employed hunter, whose income is dependent on his diligence and faithful work, is more to be relied on in the elimination of this prolific source of infection. The hunters of Nevada, cooperating with those of the U. S. Biologic Survey, disposed of not less than 12,193 true predatory animals at a net cost of $1.67 per animal during one biennial period. This was accomplished by the use of poison, by trapping and by den hunting in accordance with the season of the year. Through federal and state means, the ranchers are not only instructed in the use of poison, but it is supplied to them without cost.

Quarantine Measures.—In countries in which rabies does not occur, this favorable condition can be maintained only by a rigid supervision of the traffic in dogs, cats and other carnivora at their bounda-

ries. Either the importation of such animals should be entirely prohibited, or it must be made subject to confinement in quarantine of the animals concerned for a period of not less than 6 months. Without such measures, the cost of eradicating the disease will again have to be borne in view of the present-day means of transportation.

Management of Outbreaks.—In the face of actual outbreaks of the disease all the measures already enumerated must be applied with increased vigor. In fact, the presence of rabies in a given community often supplies the only condition which makes rigid enforcement of sanitary police regulations possible at all. To these ordinary control measures, special safeguards need to be added.

Reporting of Cases.—The occurrence of rabies should be promptly brought to the attention of public-health or livestock sanitary authorities. Cases of suspected rabies should likewise be reported. If it is at all possible to place the animals concerned in confinement this should be done. The killing of such animals should be avoided unless this proves to be the only means of securing them. If this becomes necessary, the animals should be killed in such a manner that the head be not damaged in order to prevent the destruction of the parts of the brain necessary for a definite diagnosis by microscopic methods. This precaution is especially useful in the first cases of a possible outbreak and is quite imperative if persons or animals have been bitten.

General Measures.—The authorities concerned must without delay determine the extent of the area in which animals are particularly exposed to infection, and they should immediately prescribe the control measures necessary to prevent further spread of the disease.

This should be supplemented by imparting, to the public, general information in regard to the nature of the disease, its symptoms, the dangers involved, the measures to be taken and what is to be done in the event that persons or animals are bitten.

Destruction of Rabid Animals.—All animals showing evidence or signs of rabies should be destroyed. Only if they have bitten persons or animals may it be advisable to keep them in confinement in order to await the decision of the authorities with reference to the method of further procedure, and then only when the capture of the animals can be accomplished without hazard to the captors.

Destruction of the Bitten Dogs and Cats.—In areas in which the presence of rabies has been established, all dogs and cats which have been bitten by a rabid animal should also be destroyed without delay.

Other animals, such as horses, cattle, sheep and swine, should be

secured in segregation and be kept under the supervision of the live-stock sanitary authorities. The supervision of such animals, in complete or partial confinement, should, if desired at all, extend over a period of 3 months for horses, of 4 months for cattle and of 2 months for sheep, goats and swine. Such exposed animals, however, are preferably to be disposed of for slaughtering purposes, provided they present no evidence of the disease. The carcasses of all animals affected by rabies or suspected of being so affected, must not be used for food and should be disposed of by burning or burial.

Capture and Destruction of Tramp Dogs.—Within the area involved, all tramp dogs or dogs of no established ownership (untaxed dogs) should be captured and impounded or destroyed as recommended above.

Muzzling.—The value of muzzling has been demonstrated on many occasions, although authorities are not always agreed on this point. There is no doubt that a muzzle may be so applied as to prevent a dog from biting, without constituting a manifest cruelty. When, in the areas affected, dogs are permitted to perambulate freely in public places, they should either be muzzled or kept on leash. Dogs kept in enclosures should not be subject to such restrictions.

The good results which have been secured by muzzling are probably as much to be attributed to the fact that the measure supplements the dog-tax provision as a means of restricting the volume of the dog population as to the prevention of biting.

Restriction of Dog Movements.—During an outbreak of rabies, prudence demands that dog owners keep their animals from freely moving about. Such dogs should preferably be kept in suitable enclosures so as to prevent contact with wandering canines. Of all measures this is probably the most efficient one, and at the same time it causes the least hardship to the animals concerned.

Individual Measures.—Whereas measures, pre-infection as well as post-infection, have as their special purpose the protection of the public health and the health of animals, attention must also be given to the safeguarding of individuals, persons and animals whenever the disease has manifested itself in the area occupied by them.

Persons ordinarily in a more or less regular contact with dogs and cats should, in the affected communities, avoid exposure, and even when dealing with apparently healthy animals should not permit them the opportunity of licking and biting. In this connection it is important to remember that before the expiration of the incubation period the saliva of infected animals may already be virulent.

Prompt Recognition of the Disease.—The sooner the disease is recognized the more readily can effective measures of prevention be inaugurated. When a suspected animal has bitten a person or other animal, a diagnosis must, if possible, be established either by the microscopic examination of the brain of the dog or cat which inflicted the bite, or by keeping the animal under observation while safely confined.

The finding of Negri bodies permits the earliest possible diagnosis, but it must not be forgotten that even in virulent central nervous organs they cannot be demonstrated in all the cases. The evidence gathered during the period of observation is always more conclusive, but as valuable time may be lost in the meantime, the delay may increase the hazard of persons who have sustained dangerous bites. In the event of rabies being prevalent in the community, it is a sound practice to subject such persons to Pasteur treatment and not to await a definite diagnosis. Especially in nervous, apprehensive individuals the resulting mitigation of their fears may alone justify the specific protective treatment.

Management of Wounds.—Special treatment of wounds in persons and animals bitten cannot be relied upon as a means of preventing the penetration of the virus. The severe and often cruel cauterization of such wounds may have been justified during the pre-pasteurian period as the only means of defense, but it is extremely doubtful that anything was really accomplished by such treatment. If not done within an hour after the infliction of the wound, such treatment would be too tardy, and even if undertaken with promptness, it could be considered effective only in the most superficial scratches or abrasions.

In extensive lacerations or deep wounds, any treatment, however severe and radical, would be of little value in safeguarding a patient against the development of rabies. Wounds must, of course, be subjected to suitable surgical treatment, but the idea that such treatment constitutes a protection against the disease may as well be abandoned.

Vaccination.—The post-infection vaccination, in accordance with the Pasteur method or its modifications, is the only positive safeguard to persons who were bitten by a rabid animal, even if all bites by animals thus affected are by no means infective.

Persons who have wounded themselves during autopsies or those in whom recent abrasions of the skin or even intact mucosa have been soiled with presumptive virulent materials (saliva) should be

treated in the same manner in order to secure a full measure of safety. Those bitten by an animal which dies or was killed within less than 10 days after the accident should also receive specific treatment, whenever the disease is known to exist in the area in which they live.

In the case of bitten animals, with the exception of dogs and cats, vaccination by the Pasteur or Högyes method may be considered. Horses and cattle may be so treated if their value warrants the procedure, but animals of mere slaughter value are best consigned to the abattoir.

Whether the bitten animals are vaccinated or not, they should be kept in segregation during the observation periods recommended above.

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CHAPTER XLVII

POX

THE term pox is applied to an acute, often febrile, transmissible disease of various animals, characterized by a localized or generalized vesiculo-pustular eruption and in certain species accompanied by grave constitutional disturbances.

The cutaneous eruption is the most characteristic lesion of the disease. In different animals, it may vary somewhat, but generally it consists of an inflammatory process involving both the integument and the mucosae. The eruption presents a more or less typical evolution, beginning with the appearance of small red areas which progressively enlarge, while they become slightly raised above the surface. These red, elevated areas, somewhat conical in shape, develop into a papule surrounded by a hyperemic zone.

The apex of the papule gradually pales and a vesicle is formed marked by a central depression. During the earlier stages the vesicles are filled with a clear, slightly yellowish fluid or lymph. The latter soon becomes cloudy and the vesicle is transformed to a pustule. Its contents desiccate, and the original lesion is changed to a dark brown or black scab or crust. In course of time, this becomes detached, disclosing a more or less marked cicatrix.

Sometimes the morbid process is complicated by intracutaneous hemorrhages, or the eruption may become confluent so as to give rise to large blisters and exfoliations or even deeper ulcerative processes. Secondary infections are apt to result in further complications.

The pox eruption may remain localized at certain parts of the body as in cattle and horses, or may involve the entire body surface as in man and sheep. General eruptions may also be observed in fowl-pox although in this case also, usually a tendency is manifested toward localization in certain regions of the skin.

Pox occurs in man, cattle, sheep, goats, swine, horses, birds, and has also been observed in the camel, buffalo and monkey. In general, the infection is quite specific to the animal species concerned and is but rarely transmitted from one species to another under natural conditions.

The possibility of accidental infection must be admitted and in some instances reckoned with (cow-pox in man and horse).

In all probability, pox is an ancient disease, although its first appearance among animals has not been recorded in a manner which permits a definite identification of the malady. The first account of human pox or variola was rendered by the priest-physician Aron who died in A.D. 632; the Persian Haly Abbas, who died in A.D. 994, also mentioned this disorder. Chinese chronicles go back much farther and present evidence that smallpox, or at least a pox-like disease, appeared in China about 3000 years ago.

Variola made its entry into the western hemisphere in 1517 when a Spanish vessel introduced it in Santo Domingo. During the second half of the seventeenth century variola was generally distributed throughout Europe, and since that time great epidemics have occurred in various parts of the world.

Sheep-pox was probably introduced into Europe from Asia. A first account of it dated from the second century A.D. is to be found in the Mulomedicina Chironis. The disease was mentioned in England in 1275 and in a literary production in France in 1460. The first indications of sheep-pox in central Europe date from the fifteenth century; it appears to have been observed in France in 1578, in Italy in 1691, and in Germany in 1698.

The first description of cow-pox was published in 1713; accounts of the disease in other animals bear a much later date. Fowl-pox was first described in 1775 as a conjunctivitis of chickens.

The virus of pox is filterable, passing through filters none too dense and under considerable pressure. The organism has been described as an exceedingly small, motile corpuscle. It occurs in large numbers within and between the epithelial cells and is spoken of as *Chlamydozoon variola vaccinea.* The virus apparently causes a specific reaction to take place within the cell protoplasm; as a result, demonstrable cell inclusions are formed known as Guarnieri's bodies (*Cytorhyctes vaccinae*).

In all the varieties of pox the virus is more particularly localized in the structures involved in the eruption. It is especially concentrated in the lymph of the papules and vesicles, the epithelia of the skin, mucosae and cornea apparently serving as the optimum soil for its propagation.

The virus has been demonstrated in the mucus of the nose, pharynx and trachea. During the initial febrile stage of the disease it occurs in the circulating blood as well. Pox must be considered

to be due to a generalized infection, and in the fowl, at least, its virus can be shown in the skin, brain, nerves, spleen, liver, kidneys and lungs.

Pox virus shows a rather remarkable resistance to external influences. The inspissated pus of variola pustules was found to be still virulent after years of storage. The virus is preserved by desiccation, and that of vaccinia dried on whitewash retained its potency for at least six months. The dried lymph maintained its virulence for 35 days when kept in an incubator.

The virus of sheep-pox found under the wool of affected animals remained virulent for not less than about 2 months, and in a liquid form contained in sealed glass tubes, kept sheltered against the light, it retained its virulence for more than 2 years.

Inspissated incrustations stored in a dry place and in the dark remained virulent for about half a year. In another observation the lymph of sheep-pox enclosed in glass tubes, kept in a dark, cool place, retained its virulence for 3 years. Kept at a temperature of 35° C. it remained alive for a month.

Practical experience indicated that the virus maintained itself in a stable for 6 months, and a stubblefield used by pox-infected lambs proved to be a source of infection after an interval of 62 days. On the other hand, putrefaction destroyed it rapidly.

Fowl-pox virus contained in epithelial masses remained alive for weeks, and its virulence was retained in diffused daylight during a similar period. This virus also is quite resistant to the effects of dryness.

The exposure of pox virus to a high temperature is not so well tolerated, although there are variations of behavior apparently determined by the character of the medium in which it may be contained.

A vaccine lymph heated to 60° C. for 30 to 60 minutes could still provoke pustule formation. Dried vaccine virus survived a dry heating at 100° C. for 5 to 10 minutes, but running steam destroyed it within the same time limits. Low temperatures apparently do not affect it, and alternate freezing and thawing are well tolerated by it.

Sheep-pox virus was destroyed by an exposure to 56 to 58° C. in 3 minutes, and even a temperature of 48° C. was apparently fatal to it in a short time.

The virus of fowl-pox resisted a dry heat of 80° C. for 15 to 20 minutes, but a moist heat at 100° C. killed it within 5 minutes.

It was shown that vaccine virus after a half-hour ultra-violet

irradiation had retained its virulence, whereas the bacteria present had been destroyed and spores succumbed even before the virus.

The vulnerability of pox virus varies with different chemical agents. All pox virus is quite resistant to glycerin. Fowl-pox virus suspended in glycerin and kept in the ice-chest retained its virulence for years.

Salt solutions from 10 per cent to saturation failed to impair the virulence of vaccine virus, but an exposure in bile damaged it. A similar virus was promptly destroyed by a 3 per cent solution of sublimate, but a 5 per cent phenol solution had not destroyed it after a 20-hour exposure. Potassium permanganate solutions were especially fatal to the vira of variola and vaccinia.

The virus of sheep-pox was rapidly killed by an aqueous solution of iodin (0.1 per cent), by a mercuric chlorid solution of the same concentration, and by 2 per cent solutions of sulphuric acid, sulphate of zinc, and phenol.

Fowl-pox virus tolerated a 2-hour exposure to a 10 per cent antiformin solution. It is vulnerable to sublimate and was killed by an exposure in bile for 10 hours. In a 0.5 per cent solution of phenol this virus survived for considerable periods. A 1 per cent solution of potassium hydrate killed it in 5 minutes.

Within the last decades an agreement has developed among investigators that a marked phylogenetic relationship exists between the pox of the various domesticated species, and that all pox diseases must be regarded as caused by varieties of only one pox virus, which possibly had man himself as its primary host.

In some of these varieties, differentiation has advanced so far that artificial inoculation into animals other than the optimum host rarely, if ever, succeeds. In others, such as cow-pox in man, a certain pathogenicity and immunologic relationship has been preserved. In another group these qualities have been lost in the evolution of processes of adaptation.

The inoculation of vaccinia in sheep may succeed, but no immunity against sheep-pox can be secured by it. On the other hand, horses and cattle cannot successfully be inoculated with sheep-pox virus. The transmission of variola to these animals does not readily succeed.

Fowl-pox virus has probably undergone the greatest degree of variation, even if some mammals can be successfully inoculated. It is probably nearest related to the virus of contagious pustular stomatitis of the horse.

Economic Importance.—With the exception of sheep-pox and

fowl-pox, the pox diseases of the domestic animals are of a more or less benign nature and have more of a clinical than a livestock sanitary importance. The ravages of the disease in sheep and poultry often parallel those of the human smallpox of the ante-jennerian days.

The losses caused by sheep-pox are considerable, both on account of actual death losses as well as those occasioned by the destruction of the fleece. Bands of sheep have been decimated by the malady; it has been estimated that early in the nineteenth century, one-eighth of the European sheep poulation was swept away within a space of six years. The annual loss in Hungary alone has amounted to more than 150,000 head, and in 1819 France lost more than a million sheep from this cause. In 1822 the Austrian Empire sustained a loss of 400,000 animals.

Sheep-pox declined in incidence during the last half of the century, largely on account of a reduced ovine population, as well as through the operation of rational livestock sanitary measures of a public nature.

Sheep-Pox.—Sheep-pox, although its virus is related to that of the other pox diseases, is a specific, contagious disorder of sheep, especially characterized by a pustular eruption of the skin and various mucous membranes. The disease is not communicable to other domesticated species by natural exposure.

The malady is marked by an initial febrile period and manifest catarrhal involvement of the conjunctival, nasal and oral mucosa. Within 24 to 48 hours after the onset of the fever a typical eruption declares itself in which papules, vesicles and pustules succeed one another. The latter are eventually transformed into dry, brown crusts or scabs. The eruption, however, is not always a typical one, and confluent or hemorrhagic forms are occasionally encountered. In the more severe forms of the disorder the mucosae may participate in the eruptive manifestation.

The papule formation is commonly not a simultaneous one, and various stages may be observed at one and the same time. The eruption particularly affects the bare portions of the integument or those but lightly covered by the fleece. The skin around the mouth, nostrils and the eyes, the inner surface of the thighs, the perineum, external genitals, the mammae, the ventral surface of the tail, and to a less degree, the regions of the chest and abdomen are most apt to become involved in the eruption.

Sheep-pox is always an acute disease; it runs through its course

in 3 to 4 weeks. Its epizootologic behavior may vary in different flocks. In large aggregations of sheep the invasion may be relatively a slow one, individual cases in the beginning occurring after intervals of 1 to 2 weeks. Later on, new cases succeed one another more rapidly, the spread of the infection gaining momentum as time progresses. It terminates with the involvement of the entire band with the possible exception of only a few more resistant animals which may escape demonstrable illness. In certain outbreaks the rate of speed is even more tardy, but at a later period the contagion may take on an explosive aspect.

Secondary infections may contribute to the general mortality. The latter varies greatly. In certain outbreaks the disease is rather benign, the death-rate not exceeding 5 per cent, whereas in others half of the effectives are swept away under the assault of the infection.

Sheep-pox epizootics have occurred since time immemorial in southern Europe, Russia, the Balkan states, Hungary, Tyrol, Switzerland, Germany, Italy and other areas. Asia minor, British India and all of Northern Africa have been confronted with the disease. It has not occurred in America, and Australia and apparently Japan also have remained free. The disease has manifested itself with less frequency during the last decade.

Modes and Vehicles of Infection.—In all probability the contagion of sheep-pox is air-borne. The respiratory passages absorb the virus with avidity and serve as the ports of entrance for the infection. The disease declares itself after contact with affected sheep or with those recently recovered. The period of incubation usually extends from six to ten days.

The virus may also be transmitted by means of contaminated objects or animal materials derived from affected sheep. Such fomites are: fleeces, wool, forage, bedding manure, pastures, roadways, garments and various utensils. Live carriers such as persons, dogs, cats, poultry or wild flying birds may also serve as vehicles for the infection.

Intrauterine infection apparently is possible and lambs have been borne with a well developed eruption.

The pustules and their contents are the chief sources of virus and as a rule the various secretions and excretions appear to become virulent only after they were contaminated with the moisture and débris of the skin lesions. Dried pustules in particular, play a prominent part in direct contact infection, when they are being cast off by the

skin. Hence, sheep in which the eruption has commenced to dry are especially infective.

Factors Favoring Infection.—Not unlike other diseases, sheep-pox is less malignant or virulent in regions where it is enzootic than in others where the infection only occasionally makes an incursion. Thus, sheep-pox is relatively benign in the Mediterranean countries, where it is always more or less prevalent. In the area mentioned, the average mortality ranges between 2 and 5 per cent. However, when Algerian sheep, which carried the infection, were introduced into France, the native sheep exposed to them developed pox of a much more malignant type.

Young animals more readily contract the infection than older ones and among the lambs involved in an outbreak, the mortality may be exceedingly high.

There is a difference in the susceptibility of the various breeds of sheep. Apparently the Merino breed and those closely allied to it are most liable to suffer from the disorder.

One attack of the disease is followed by a solid immunity to subsequent infections which may endure for several years.

Prophylaxis. *Sanitary Measures.*—Among the sanitary measures, the ones which prevent the extension of the disorder to countries hitherto free of infection, or to clean areas adjacent to those where sheep-pox is prevalent, are of the greatest importance. The importation of sheep from countries where the disease is enzootic or momentarily prevalent should be rigidly prohibited. The same restrictions should be applicable to hides and fleeces of the same origin, unless such materials are adequately disinfected.

In districts where the disease is actually present, infected herds and premises should be segregated by quarantine measures. The advisability of compulsory inoculations of animals yet free from the disease, in involved herds, must be given consideration in order to restrict the duration of a given outbreak. This measure, however, may be omitted if the immediate slaughter of the disease-free animals within a short space of time is contemplated. In the control of local outbreaks, inoculated sheep must be included in the quarantine restrictions enforced against affected flocks.

Immunization.—A method of protective inoculation, comparable to variolization against smallpox, has been practiced since early times and is even now still in use in several regions. It is known as clavelization or ovination. The practice consists of an intracutaneous inoculation with non-attenuated sheep-pox virus.

For this purpose, the clear, yellowish or reddish yellow lymph of fresh sheep-pox vesicles is selected. The virus is introduced into the substance of the skin by means of an inoculation needle or a superficial scarification. The ventral surface of the tail 2 or 3 inches from the anus, or the inner surface of the ear half an inch from the tip, is commonly preferred as the seat of inoculation.

Sheep which have been subjected to clavelization are still able to transmit the disease, and hence the practice should be limited to flocks actually involved in an outbreak. It should not be used as a preventive measure in disease-free areas or flocks as it is apt to establish more or less enduring infection foci.

Clavelization is merely an emergency measure, which causes a rapid sickening of the entire flock, but the resulting illness is, as a rule, of a milder form than that induced by natural infection. The procedure is followed by a substantial immunity.

The essentials of a desirable method by which sheep can be immunized against pox consists of conferring an active, durable immunity by the use of an inoffensive virus without the establishment of infective lesions. This was first attempted by Borel by means of sero-clavelization in which a virus and an immune serum were simultaneously injected. Some success was attained by this method although it failed to solve the problem.

A greater measure of success was achieved with the sensitized virus of Bridré and Boquet. For this purpose, a virulent pox lymph is kept in contact with a highly potent immune serum at 15 to 18° C. for 3 days. The mixture is then centrifuged and the sediment thus obtained diluted with a physiologic salt solution so that 1 c.c. contains 5 m.g. of the precipitated material. This suspension in doses of 0.2 c.c. is subcutaneously injected in the region posterior to the elbow, below the margin of the wool and at the posterior border of the parts covered by hair. Care must be taken not to deposit any virus into the skin.

The experiments of the originators of this method showed that the inoculation is followed by a minimal thermic reaction, the intensity of which has no relation to the importance of the local reaction which may, indeed, not be observed even when the temperature becomes quite high. The local reaction which may follow is a subcutaneous one from which no virus can escape on the surface and hence is non-infective.

The sensitized virus inoculation has no unfavorable influence on animals already infected and hence can safely be used in infected flocks. The immunity engendered by the inoculation endures for a

year at least, and as early as 48 hours after the injection the animals are already protected against a natural exposure.

In Algeria between January 1 and June 15, 1913, more than a million and a quarter sheep were treated with sensitized virus without a single report of untoward results.

Fowl-Pox and Canker.—The pox-canker of fowls is a transmissible disease of birds, distinguished by cutaneous eruptions, diphtheritic lesions of certain mucosae and systemic disturbances.

Formerly the pox eruption of the skin and the canker lesions of the mucous membranes were regarded as manifestations of two separate and distinct pathologic entities. Although the possibility of a diphtheritic disease not caused by the pox virus must be admitted, it is now generally accepted that pox and canker have this virus as their common etiologic factor.

The disease affects fowls, turkeys, pigeons, pheasants, guinea-fowls and pea-fowls and has been observed in certain wild birds. Pox-canker has been described in ducks and geese, but on the whole it must be regarded as a rather uncommon disease in water-fowls.

As already mentioned, the virus of fowl-pox and canker is a distinct variety of a primitive pox virus, and it must also be regarded as quite possible that certain sub-varieties have to be reckoned with as the etiologic factors of the pox diseases encountered in the various avian species. The pox-canker disorder of the common fowl only has thus far attained an economic and livestock sanitary importance.

Pox and canker either occur simultaneously in one and the same fowl, or, in the same flock, birds may be affected by but one of these forms of the disease. In certain outbreaks, pox only is encountered, whereas in others the canker form prevails exclusively.

The pox eruption is most commonly observed to involve the skin of the comb, wattles, eye-lids and other parts of the head. In the more malignant forms of the disease, the integument of other parts of the body is apt to participate in the eruption.

The initial phase of pox formation is marked by grayish white elevations of the epidermis which later take on the aspect of more or less voluminous wart-like formations. In the final stage these are transformed into brownish, dark brown or reddish brown incrustations. The affected areas may become involved in secondary infection as a sequel to the primary disease. These may result in a substantial tissue destruction.

The canker form of the disease in a preponderating number of the cases involves the mucosae of the mouth, eye and nose, although

participation of the deeper air passages and esophagus is by no means a rare phenomenon.

The lesions of canker consist of a more or less chronic, croupous, diphtheritic inflammation of the mucous membranes concerned. Probably also on account of intercurrent infections of varying nature, canker is the more malignant form of the malady.

The uncomplicated pox localized on comb and wattles is, on the whole, of a more or less benign character. In the more malignant outbreaks of pox and canker pathologic changes in visceral organs are commonly observed.

The disease in both of its forms occurs in more or less extensive epizootics, and in a given flock it may endure enzootically. Pox-canker is widely distributed in all countries where poultry husbandry is extensively practiced.

Especially where the canker form of the disease prevails, a high mortality rate (50 to 75 per cent) may be observed, and even in the more benign outbreaks it is capable of inflicting serious damage by the concomitant reduction of production and by its depreciating effect on constitutional vigor.

Modes and Vehicles of Infection.—Fowl-pox and canker present many of the characteristics of a very contagious disease. Healthy flocks are apt to become infected through the introduction of new stock and by means of birds returning from shows. Wild birds may also play a part in the dissemination of the virus, and a considerable volume of evidence shows that fowls which recovered from the disease may carry and transmit the virus during prolonged periods.

In canker outbreaks especially, the virus is widely and abundantly distributed. Owing to the marked resistance of the fowl-pox virus to desiccation, it may survive for a considerable time in a given environment, particularly during the cooler seasons of the year.

Within a flock, the spread of the disorder comes about by direct contact as well as through the agency of contaminated food and water. As the virus may be eliminated by the feces, the soil also may serve as a vehicle. Exfoliated epithelia from the parts involved in the eruption, as well as the discharges from the affected mucous membranes, are to be regarded as very potent agents of transmission.

Intermediary living carriers, as well as contaminated houses, foodstuffs, and utensils, may play a part in the transportation of the disease from farm to farm. Some observations of the author in a region badly infested by mosquitoes (*Culex and Anopheles*), induced him to suspect these insects of playing a part as vectors of the virus.

The incubation period of pox and canker ranges from 4 to 8 days after experimental inoculation and from 10 to 21 days after natural contact.

Factors Favoring Infection.—Among the factors which apparently favor the spread and occurrence of pox and canker a seasonal influence, no doubt, plays an important part. Autumn and winter always show the greater incidence of the disease, although cases, or outbreaks even, may be encountered throughout the entire year.

This is probably associated with the tendency of fowls to remain longer in close contact within their shelter during the shorter days of the colder season although the effect of chilling and dampness cannot be readily excluded. On American farms the younger birds often remain outside, roosting in trees during summer and early autumn, and it is a common observation that, when inclemencies of the approaching winter season force them to find protection indoors, extensive outbreaks of pox, and especially canker, declare themselves.

Over-crowding, no doubt, contributes toward a rapid spread of the malady, and it has frequently been noted that rapid spread and malignancy in the individual cases are concomitant phenomena.

The younger birds always show a more striking susceptibility to pox and canker than the older members of a flock, and the higher mortality may be predicted for fowls less than a half year old. The more refined and improved breeds are probably more liable to pox and canker infection than the more common barn-yard varieties.

Recovery from the disease is followed by immunity, although as a rule this is rather slow in its development.

Prophylaxis. *Sanitary Measures.*—The exclusion of infection from healthy flocks must always be attempted by preventing newly acquired fowls or those returning from shows or fairs from mingling with a normal stock. Such birds should be kept in segregation for from 2 to 4 weeks for the purpose of observation. The mere isolation, however, is not sufficient, inasmuch as the segregated fowls may be carriers or spreaders of the virus without presenting evidence of their status in this respect. Hence, two or more young, normal fowls should be kept in contact with those primarily under observation as an additional test for the presence or absence of pox virus.

It must be admitted that a salubrious environment, adequate nutrition and the periodic disinfection of poultry houses and their appointments cannot but have a certain prophylactic value. The prompt elimination of the first fowls showing evidence of the disease is always a more important sanitary measure, second in efficacy only

to the prudence exercised in regard to new stock to be introduced into the flock.

These measures should be supplemented by the prevention of over-crowding in the houses at the approach of colder weather. Quite early in autumn all surplus stock should be disposed of in order to reduce the flock to a minimum compatible with production requirements and housing facilities.

Immunization.—Since Manteufel, in 1910, showed that fowls intravenously or subcutaneously inoculated with a finely triturated suspension of fowl-pox material developed a high degree of immunity, various attempts to prevent the disease by protective inoculation have been made. The method with which Manteufel experimented, however, did not exclude the hazard of serious post-vaccination sequelae and hence found no practical application.

Hadley and Beach (1913) and Mack and Records (1915) experimented with fowl-pox virus prepared from the dry crusts gathered from typical pox-eruptions. This material was thoroughly triturated, suspended in a physiologic salt solution and heated for 1 hour at 55 to 58° C. These workers reported some measure of success after subcutaneous injections of 1 c.c. of the suspension, although this could not always be substantiated by other observers. Hadley and Beach estimated that in their successful attempts the immunity thus engendered endured for 1½ to 2 years. Mack and Records regard two or more injections as advisable.

Other attempts were made with a bile-treated virus, with a fowl virus attenuated by pigeon passage, or by the addition of phenol. DeBlieck and Van Heelsbergen attenuated an originally very virulent virus until it had lost its malignant character and reported favorable results when such virus was used for protective inoculations. The method of attenuation, however, was not disclosed.

Van Heelsbergen speaks hopefully of a proprietary immunizing agent by means of which even chicks 4 weeks old can be successfully treated. With a small trephine-like scarifier the skin of the leg is lightly abraded and the immunizing substance rubbed in. An inoculation reaction appears from 8 to 10 days after the treatment. Unless such a reaction declares itself, no protection can be expected, hence it is desirable to inspect the treated birds about 8 days after the inoculation.

It is as yet questionable whether or not an efficacious and safe method of fowl-pox control by immunization has been achieved even if apparently successful attempts have been recorded.

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CHAPTER XLVIII

THE PIROPLASMOSES

THE name piroplasmosis is applied to the diseases of infection caused by non-pigmented protozoan parasites of the erythrocytes, which, for their natural transmission, depend on arthropod vectors belonging to the family Ixodidae.

The piroplasmoses must certainly have existed in many areas for centuries, but as in the case of so many of the transmissible disorders, which had to await the advent of the Pasteurian era, it was not possible to separate piroplasmosis from the many maladies which then were equally obscure. The early history of this group of diseases will remain in the dark and all that is now more accurately known about them has been ascertained within the last hundred years.

No doubt, the disease was observed during earlier times, as reference to "red-water," "mal de brou," etc., may occasionally be found in the older writings. In 1834 it was more definitely described by Blaser of Switzerland, and since then mention of "red-water" and "wood and moor ill" became more frequent.

The earlier history of the piroplasmosis of this country is equally obscure. Cary mentions that the disease, near the close of the eighteenth century, appeared in Lancaster County, Pennsylvania, and that it was introduced there by a shipment of cattle coming from North Carolina. About 1868 this disease began to engage the attention of people engaged in the cattle trade and grazing operations. In the course of that year, Texas cattle transported on the Mississippi River, upon reaching their destination in the states of Illinois and Indiana, communicated a malady, often fatal, to the native stock.

As similar disasters frequently followed the introduction of Texas cattle, the then highly mysterious malady became generally known as the Texas fever. How the disorder was introduced into this country is entirely a matter of speculation. The most plausible hypothesis is that it came with the importation of Spanish cattle to the coast region of the Mexican Gulf and the adjacent islands.

By the time that the present U. S. Bureau of Animal Industry was organized, Texas fever had assumed a character of national importance, and its earlier efforts in research were largely devoted to bringing clarity to the problem. The momentous discoveries of Smith and Kilborne were the consummation of these attempts, and in 1889 they settled the question for all time. In one of the great classics of comparative pathology and epizootology they revealed the etiologic factor and the essential part played by an arthropod vector.

Most of the piroplasmoses are diseases peculiar to tropical and subtropical regions. Wherever the prevailing temperatures permit the vector ticks to live and to complete their life cycle, these maladies may be found to occur. Northern climates and high altitudes are not conducive to the propagation of the diseases included in this group. However, even there piroplasmosis may make seasonal incursions when parasite and vector are introduced with livestock from the permanent foci of infection. At one time the Texas fever of the southern United States caused serious losses among the cattle of the northern ranges of this country, when during the grazing season southern cattle were introduced among them.

The Texas fever area of the American continents originally extended from the 37th degree latitude north to the 35th degree latitude south. In Europe this disease is reported from the more southern parts of the continent, where the affected areas correspond with the range of distribution of the vector tick *Boophilus annulatus*. The "red-water" of central and northern Europe is apt to declare itself where the tick *Ixodes ricinus* may be found and where it has opportunity to feed upon cattle infected with the blood parasite *Babesia bovis*. The disease has occurred even in countries as far north as Norway and Finland.

Piroplasmoses occur on the entire continent of Africa, and in Australia only the southern areas appear to be exempt. Disorders belonging to this group are reported from the tropical or subtropical portion of the Asiatic continent, and the archipelagoes of the Pacific also appear to be foci enzootically involved.

The clinical manifestations of the various disorders classified as piroplasmoses vary in accordance with the animal species concerned and the parasite etiologically responsible. In general, they include dullness or languor, high body temperature, digestive disturbances, icterus, anemia and hemoglobinuria. In Texas fever the animals separate themselves from the herd. They move about with a straddling gait or stand with the head lowered and the back arched.

Petechia, even ecchymoses, may develop in the mucosae, and edema of the eye-lids may be seen.

In cases of coast fever the disease is initiated by a sudden rise of the body temperature. There are lachrimation, discharge of nasal mucus and driveling from the mouth. Diarrhea is sometimes noted, and the feces may be bloody. Severe dyspnea may arise from pulmonary edema, and a frothy, nasal discharge may serve as evidence of pronounced respiratory distress. Tumefaction of the superficial lymph nodes is observed, but in contrast to the other disorders included in this group, anemia and hemoglobinuria are not observed in coast fever.

In most of the piroplasmoses, variations in the severity and intensity of the clinical features are observed. The symptoms may denote a marked malignancy, or a milder course may also be observed. In some of the piroplasmoses the disorder may assume a more or less chronic character.

Death by exhaustion, general collapse and coma is a not uncommon termination in the various maladies belonging in this group.

The post-mortem changes presented by the piroplasmoses include impairment of the various parenchyma and involvement in a progressive necrobiosis. The spleen is enlarged, and petechial and ecchymotic hemorrhages indicate that the capillary endothelia participate in the general tissue damage.

In Texas fever, the carcass is usually reduced in flesh; there is edema of the subcutaneous connective tissue, which commonly shows an icteric tint. The spleen is markedly enlarged and of a steel blue color; the pulp is brownish red. The liver is brownish yellow; the kidneys are swollen, dull grayish red, to dark red in color. In coast fever this organ presents small nodules, lymphomatous in nature, and the lymph nodes are hyperplastic.

Except in coast fever, anemia is a rather constant feature in all the piroplasmoses. Within a short time after the first manifestation of illness the red cells may have become reduced to 20 per cent of their normal number. Anisocytosis and poikilocytosis are observed, and in cases of some duration erythroblasts may make their appearance. In coast fever the spleen is not enlarged and may even be atrophic.

The myocardium is commonly impaired, and especially in the piroplasmosis of sheep this impairment is apt to give rise to marked edema of the subcutaneous connective tissue. Gastro-intestinal lesions are often observed.

The piroplasmoses are essentially pasture diseases, their transmission depending entirely on the presence of animals harboring the micro-parasites and of the tick species which may serve them as vectors.

Prior to the discoveries of Smith and Kilborne, the most perplexing phenomenon in the epizootology of Texas fever was the sickening of cattle on northern ranges shortly after southern cattle were introduced among them, while the latter remained in a good state of health during the outbreak. Their discoveries showed that the epizootology of piroplasmosis is a relatively simple one in which the factors of infected animals, ticks and susceptible bovines are dominant.

At the time when the etiology of the malady was revealed, it was already known that not all cattle showed the same degree of susceptibility. Animals born in the areas of distribution of the parasite, as well as of the vector ticks, are quite resistant if not entirely refractive to the disease. It could, however, be shown that such animals harbor the piroplasmae, and that, through the agency of the ticks, the disorder could be induced in bovines originating in a tick- and disease-free territory.

It developed further that animals native to the tick-infested south are not resistant because of any genetically acquired qualities, but that a piroplasma invasion early in life was the base upon which resistance was founded. Apparently during this life period host and parasite develop a mutual tolerance or adaptation. This host-parasite relation probably persists during the life of the host. The piroplasmae inhabit the host only in small numbers, which are tolerated with impunity as long as disturbing factors do not upset this ideal arrangement.

On the other hand, if cattle native to Texas fever territory are born and grow up in places where they cannot become infested with infected ticks while they are young, they are as apt to succumb to the malady as northern-bred animals from tick-free districts. In the southern states of this country, Texas fever was long known as "towncow disease" because cows reared in tick-free city enclosures promptly sickened when ticks gained access to them during a later life period.

It is, however, possible that a genetically acquired resistance to piroplasmosis may be observed. This pertains to ancient breeds developed in countries where, for centuries, natural selection could, in the face of an ever-present piroplasmosis hazard, establish a racial

resistance. The reputed resistance shown by the sacred cattle of India may be an example of such a congenital non-susceptibility. Conclusions on this point should not be rashly made and can be based only upon the resistance shown by young adults, born and raised in tick-free territory, when they are exposed to tick infestation in infected territory.

The wide distribution of the piroplasmoses and the high mortality which accompanies most of the disorders included in this group are accountable for their constituting a major problem in livestock sanitation.

In many areas the ticks *per se,* as well as the maladies transmitted by them, are a severe inhibition to the development of profitable animal husbandry. The mortality of piroplasmoses shows variations in accordance with the age and physical condition of the animals concerned. It ranges between 50 and 90 per cent for affected adults in most of the diseases belonging to the group.

As late as 1914, Mohler estimated that, in the southern states of the American union, the ticks were responsible for an annual loss of $40,000,000 to the people of the area involved, and that the assets of this section were reduced by an additional $23,250,000 by the same factor.

In the Transvaal, 50,000 head of cattle died of coast fever in the year 1905, and in German East Africa 20 to 25 per cent of the progeny of native cattle succumbed to the disease.

Expedience warrants the consideration of anaplasmosis with the disorders belonging to the piroplasmosis group. The disease has many clinical and patho-anatomic characters in common with the latter. Anaplasmosis and Texas fever are commonly encountered in the same animal. Evidence of anaplasmosis takes the form of the presence of small, punctiform, round or oval bodies within the erythrocytes. These bodies are, by good authorities, accepted as protozoa closely allied to the Piroplasmidae and regarded as etiologically connected with the malady. Other investigators look upon these bodies as mere cell inclusions incidental to a morbid process caused by a virus as yet unknown.

Host Species.—Protozoan blood parasites belonging to the Piroplasmidae are quite widely distributed in nature. They occur in all the domesticated animals and have been reported as observed in several wild, living species such as the monkey, zebra, giraffe, deer, reindeer, antelope, jackal, bear, hedgehog, mole, hare, cavia, rat, fieldmouse, sloth and others. The economically more important host

species and the disorders of piroplasmodic nature to which they are liable are indicated in Table I.

Although a given host species may harbor more than one member of the Piroplasmidae, the latter are only parasitic for one single host, or at the most, to species phylogenetically closely related.

The micro-parasites of the piroplasmoses belong to the suborder Piroplasmidae. They inhabit the erythrocytes of mammals in which they do not form pigment. They are divided into the families Babesidae and Theileridae. Each of these has been further separated into several genera. As the bases for a definite classification are as yet not very secure because of a certain lack of detailed knowledge pertaining to the life history and other essential biologic characters of these protozoa, the grouping proposed by Wenyon is accepted for this text. Hence for the genera of piroplasmae only the designations *Babesia* and *Theileria* will be retained pending further developments in their taxonomy. Although this may deviate materially from what is now accepted in current literature it will at least serve the cause of simplicity. (See Table I.)

The genus *Babesia* includes the motile, endoglobular parasites of mammalian blood which reproduce themselves within the erythrocytes by division in 2 or 4 daughter cells. The *Babesia bigemina* of Texas fever is typical of this group of piroplasmae. They occur as pear-shaped, oval, round or irregular bodies varying in size in accordance with the species. The *Babesia* of Texas fever is one of the largest, the pyriform parasites measuring from 2 to 4 microns in length.

In the blood of animals sick with the disease they are present in considerable numbers. In most cases about 1 per cent of the red corpuscles is occupied by the micro-parasites. Cases have been observed in which more than half of the red cells were thus invaded. In the permanently infected animals they commonly occur in such small numbers that they escape microscopic observation altogether and inoculation experiments would be required to demonstrate their presence.

The genus *Theileria*, typified by *Theileria parva* of African East Coast fever, includes parasites which do not multiply in the blood cells. The forms present in the latter are incapable of reproduction. This, in the mammalian host, takes place by schizogony in the vascular endothelium and from there the parasites invade the erythrocytes. There they appear as single, motile, round, oval or bacillary forms. The spherical forms measure 1 to 2 microns in diameter. From 80 to 90 per cent of the blood corpuscles may be invaded by them.

TABLE I. THE ECONOMICALLY MORE IMPORTANT PIROPLASMOSES

Host species	Disease	Parasite	Area involved	Vectors
Cattle	Texas fever	*Babesia bigemina*	North America	*Margaropus annulatus*
	Tristeza	*B. bigemina* *B. argentina*	South America	*Boophilus microplus* *B argentinum*
	Piroplasmosis bovis	*B. bigemina*	Cuba, Brazil, Venezuela	*Boophilus australis*
		B bigemina	Africa	*B. decoleratus* *B australis* *Rhipicephalus appendiculatus* *R. evertsi*
		B. bigemina	*Australia*	*B. australis*
		B. bigemina	Asia	*B. australis* *B. calcaratus*
		B. bigemina	England	*Haemaphysalis cinnabarina punctata*
		B. bigemina	So. Europe	*B. annulatus*
	Red-water Mal de brou	*B. bovis* *B. divergens*	Europe	*Ixodes ricinus*
	Bovine malaria	*B. mutans*	South Africa	*Rhipicephalus appendiculatus* *R. evertsi*
	Coast fever	*Theilera parva*	South Africa	*R. appendiculatus* *R. evertsi* *R. capensis* *R. simus* *R. nitens*
		T. parva	Macedonia	*R. bursa*
	Anaplasmosis Gall sickness	*Anaplasma marginale* *A. centrale*	South Africa	*B. decoloratus* *R. simus*
		A. Argentina	Argentina	*B. microplus* *Amblyomma* sp.
		A. marginale	North America	*Dermacentor occidentalis* (?) *Ixodes ricinus* var. *californicus*
Sheep	Ovine piroplasmosis Icturo-hematurio Carceag	*B. ovis*	Balkan States	*R. bursa*
	Anaplasmosis ovis	*A. marginale*	Africa	?
Horse	Equine biliary fever Equine malaria	*B. equi*	South Africa	*R. evertsi*
		B. equi	South Russia	*Hyalomma aegypticum* *Dermacentor reticulatus*
		B. equi	Rumania, Italy	*R. bursa*
		B. caballi	South Europe	*D. reticulatus* *B. annulatus*
Asses and mules	Piroplasmosis equi	*B. equi*	South Africa	*R. evertsi*
Dogs	Piroplasmosis canis	*B. canis*	South Africa	*Haemaphysalis leachi*
		B. canis	India, North Africa	*R. sanguineus*
		B. canis	France	*Dermacentor reticulatus*
		B. gibsoni	India	*R. simus* (?)
	Nambi-uvũ	*B. vitalli*	Brazil	*Amblyomma cayenense* (?) *A. striatum* (?)

All the piroplasmae are transmitted by vectors belonging to the family of the Ixodidae. The ticks serve them as intermediary hosts, and they are, to a large extent, specific for each protozoan species. This specific host-parasite relation is, however, not as narrowly defined as that between mammalian hosts and their blood parasites inasmuch as a given piroplasma may be transmitted by more than one tick species. A given tick species may also serve as intermediary host to more than one species of piroplasm. (See Table I.)

Although but little is known relative to the development of the piroplasmae in the tick, evidence is not lacking which indicates that certain essential phases of their life cycle are completed in the specific vector.

The specific blood parasites can in nature exist only in the body of their mammalian or arthropod hosts. They do not occur elsewhere, but within either host they are able to maintain themselves for extended periods. In Texas fever blood kept in the ice-chest, *Babesia bigemina* retained its virulence for 50 days.

The larger species of *Babesia,* as they occur in the blood, appear to be vulnerable to solutions of trypanblue when these are injected intravenously even if the blood of animals so treated remains infective for several years.

Modes and Vehicles of Transmission.—The piroplasmoses are not transmitted by direct-contact infection, and in the state of nature, transmission can come about only through the agency of the vector ticks. (See Table I.) Thus, under natural conditions, these diseases can be propagated only when infected animals, the specific ticks and susceptible livestock are present in a given area. Owing to the longevity of the ticks, this presence does not always need to be a simultaneous one.

Animals sick with the disease or those which have recovered from it contain the parasites in the blood. An exception to this general rule, however, is supplied by coast fever, the *Theilera parva* disappearing from the blood after recovery from the disease. Hence, the animals which survive an attack of coast fever do not become spreaders and play no further part in the dissemination of the malady as they do in Texas fever. Only cattle actually sick with coast fever and the ticks they harbor may be instrumental in transmission.

In other piroplasmoses such as Texas fever, when the animals which have recovered from an attack of the disease, or presumably have done so, inhabit a territory where the disorder occurs enzootically, they continue to harbor the piroplasmae for long periods,

probably during the remainder of the life of such hosts. Schroeder reported the case of a cow the blood of which remained infective for a period of 12 years.

Such animals can readily carry the disorder to cattle occupying disease-free areas, provided, of course, that the specific vector tick is also available. Before the anti-tick quarantine measures of a later day, the ticks were usually carried by the same cattle which harbored the piroplasmae. In this manner Texas fever became a serious problem on the northern ranges soon after southern cattle were introduced there.

With the exception of coast fever, the piroplasmoses may, however, be artificially transmitted by means of intravenous, intraperitoneal and subcutaneous inoculations of the blood or organ suspensions taken from diseased or carrier animals. A very small quantity of virulent blood is often sufficient to cause the disease in a susceptible animal, and positive infection is even possible when the blood is placed upon an area of scarified skin of such a subject.

The mode of pathogenesis of the piroplasmae is by no means clear. Toxic substances are suspected to play a part, but have not been specifically demonstrated. Their presence is suggested by the fact that in canine piroplasmosis active antibodies could be shown.

The destruction of the erythrocytes is evidently the most conspicuous result of the action of such hypothetical substances. The parenchyma of other important organs is likewise vulnerable to their action.

Animals may become simultaneously invaded by more than one species of piroplasma. Schilling and Meyer point out that when European cattle are introduced into South Africa and then inoculated later with blood of a native animal, the following phenomena may present themselves: After 8 to 10 days the animals sicken with Texas fever. If they recover, another fever attack declares itself in 26 to 28 days with symptoms of anemia and the appearance of the marginal points characteristic of anaplasmosis in the blood cells. If the animals recover again, then 40 or more days after the injection *Babesia* (*Gonderia*) *mutans* may be demonstrated in their blood.

In the natural transmission of the disease the piroplasmae are taken up by the ticks while feeding on the blood of the invaded animal. The parasites complete part of their life cycle within the structures of the tick, and, in the case of Texas fever, they are passed into the eggs and from these to the larvae and by the latter to a new host. In the case of the two or three host ticks, the larvae and

nymphs only may be the transmitting forms. Thus, in the European red-water fever, either the larvae or the nymph may suck the virulent blood and pass the parasites to the form succeeding in the metamorphosis.

In the transmission of *Babesia ovis,* the vector tick, *Rhipicephalus bursa,* passes the parasite to the egg, but neither larva nor nymph is able to infect, infection being possible only through the agency of the mature form. *Babesia equi* is taken up by the larva or nymph of *Rhipicephalus evertsi* and transmitted by the imago.

The three host ticks, *Haemaphysalis leachi* and *Rhipicephalus sanguineus* which are the vectors of *Babesia canis,* pass these parasites to the eggs, but only the mature ticks can transmit them, both larvae and nymphs being incapable of doing so.

Theileria parva of coast fever is never transmitted by the female tick to her eggs. Consequently, the larvae of the vector ticks (see Table I) are never infective, not even if the parent tick has fed on an animal actually sick with the disease. In the event of the larvae gaining access to such animals, it may pass the parasites to the succeeding form in metamorphosis, the nymph, which then becomes infective and capable of transmitting the disease to the susceptible bovine, which may serve as its host. If virulent blood is first taken up by the nymph, the imago may become a vector for the parasites.

An interesting phenomenon is presented by the fact that it is apparently impossible for the vector ticks of coast fever to infect twice. If as nymphs they transmitted the disease, they are no longer able to do so after their transformation to mature ticks. They are described as having "cleaned" themselves. This is also the case with the sexually mature ticks. It was experimentally shown that a tick after having actually infected an animal and then removed to a second susceptible host has become harmless to the latter. It was even showed that such ticks became "clean" after a feeding on such insusceptible hosts as the horse, sheep or rabbit.

In the case of *Rhipicephalus evertsi* only the mature tick can transmit *Theileria parva,* and all the vector ticks of coast fever can infect themselves only by feeding on animals during the attack of the malady. Nor can this disorder be transmitted artificially by injections of blood. On the other hand, it is possible to do so when particles of spleen or lymph nodes are used as the inoculum.

Only a few ticks are required in the transmission of the piroplasmoses. In the case of coast fever, the disease was successfully induced by a single tick.

The incubation periods of the piroplasmoses vary somewhat in length. As a rule, the incubation is shorter after an artificially induced infection. In *Babesia* infections of cattle the period of incubation ranges from 8 to 14 days, of sheep 8 to 10 days, of horses 5 to 9 days after artificial inoculation and about 3 weeks after tick infestation. Dogs infested by the vector ticks sicken in 13 to 21 days.

Coast fever shows incubation periods of 10 to 15 days, and anaplasmosis is characterized by long incubation periods, from 16 to 47 days after artificial inoculation and from sixty to eighty days when infected by ticks.

Factors Favoring Infection.—Aside from the factor of age of the hosts, the vulnerability of the vector ticks to prevailing low temperatures and other meteorologic influences is about the only one which may materially influence transmission or the severity of the resulting malady. Thus, during the cooler seasons of the higher latitudes or altitudes, the spread of the piroplasmoses is slower and in some instances their mortality rate may also become reduced.

The incidence of both Texas fever and coast fever is increased by humid, hot weather. The latter disease is always most malignant in areas of low altitude; in regions from 4600 to 4800 feet above sea-level, the rates of spread and of mortality are more favorable than in lower districts. Under these conditions the older animals are not so apt to acquire resistance and when moved to lower levels are more liable to the disease than those which remained there.

The younger animals are, as a rule, more refractive to infection by the various *Babesia* than the older, susceptible cattle. Calves less than 9 months old always have a better chance to recover, and in younger calves, which, in regions where the diseases are enzootic, scarcely ever escape infection, when exposed to ticks, the disease may be so mild that it escapes observation altogether. As has already been pointed out, such animals continue to harbor the parasites, but on the whole show a degree of resistance sufficient to protect them against the results of subsequent invasions.

With regard to coast fever, the younger animals appear to be more susceptible than the adults. The fact that the older animals belonging in the same environment may have acquired resistance as a sequel to a non-fatal attack earlier in life must, however, be given weight, when comparing the susceptibility, *per se,* shown by the various age groups.

The resistance acquired through a previous invasion by any of the piroplasmae such as the one causing Texas fever is by no means

an absolute one. It was shown, for instance, that when animals resistant to a piroplasma peculiar to a given region were exposed to parasites specifically identical, but originating in other parts, their protection against them was inadequate. Observations of repeated attacks of the disease sustained by such resistant animals have also been recorded. In the light of such evidence, it becomes doubtful that the protection afforded by a previous invasion is of the nature of immunity such as may be encountered in the bacterial diseases.

The parasites harbored by the resistant animal have by no means lost their virulence, and even in these hosts themselves, slight disturbances in their general condition, as induced by unaccustomed hardships incidental to transportation, by intercurrent sickness, by over-exertion or by sudden changes of the weather, may bring forth a new attack of the malady (Texas fever). Even such an apparently benign influence as the injection of anti-cattle plague serum has caused a latent piroplasmosis to flare up again. Eassie reported that continued exposure to a tropical sun was seemingly responsible for an exacerbation of piroplasmosis in previously resistant horses. In coast fever the resistance induced by a previous infection is more substantial. It more closely resembles a true immunity.

The more refined breeds of cattle are apt to suffer more severely from the piroplasmoses than the coarser, native cattle of an infected territory. During the hotter part of the year the losses among the former may reach the maximum.

Prophylaxis.—The ways and means of prophylaxis of the piroplasmoses must of necessity vary in accordance with the magnitude of the problem associated with this group of diseases. Thus, the measures applicable to the control of the relatively scattered and sporadic European red-water fever would be entirely inadequate or even impossible for the suppression of the bovine piroplasmoses of South Africa, Australia and America. On the other hand, the labor and expense involved in the methods required in order to cope with the problems connected with the latter would be entirely out of proportion to the value of the results which may be achieved in the case of the former.

Against the red-water fever of Europe in which usually small groups or units of cattle are concerned it is often possible to succeed by avoiding the pasturing of the animals on ground known to be tick infested. Prevention may be accomplished by stable feeding and by the use of artificial grazing grounds. Pasture rotation in the general scheme of agricultural practice and the amelioration of the

land by the removal of brush and other rank growths and by the appropriate drainage of swampy areas has been proved to be useful in the prevention of the malady.

It is obvious that, in the face of the disease, care must be taken that animals infected or presumed to be carriers of *Babesia bovis* be thoroughly disinfested before their admission to a clean pasture ground. Similar measures are also applicable to the piroplasmoses of other animals as long as the diseases do not constitute a major problem in livestock sanitation.

In parts of the world where tick infestation and piroplasma invasion involve a considerable portion of the livestock population and where, in addition, the practice of grazing is the only method of animal husbandry adapted to local conditions this group of diseases may become such an obstacle to the development of a profitable industry that even its very preservation may call for the most energetic efforts in prevention and control.

Among these, tick eradication occupies the most prominent place. Wherever this is at all possible it is the method of choice and remains, after all, the most economical one. As the various methods employed to this end were given consideration in another chapter devoted to disinfestation and disinfestants, they will require no additional mention at this place.

The success in tick eradication in the southern United States (see Fig. 77) and other territories may serve as an illustration of its feasibility, even in spite of the enormity of the task and the many obstacles which have to be overcome.

The prompt and adequate dipping of the animals exposed to coast fever will almost at once check further dissemination of the disease. In the Transvaal, efforts in general disinfestation are supplemented by sanitary police measures, which provide for the slaughter of the animals involved in isolated outbreaks and the reimbursement of the owners.

The prevention of new outbreaks of coast fever is attempted by the following measures: The temperatures of all animals in infected pastures are taken; the ones with normal temperatures are removed to a tick-free enclosure, and the febrile ones are either left where they are or destroyed. Temperature control of the fever-free animals is continued daily, and those which develop fever are removed from the lot or killed. The cattle which remained free of fever are removed on the sixteenth day in order to escape any hazard associated with ticks which may have dropped from an infected animal.

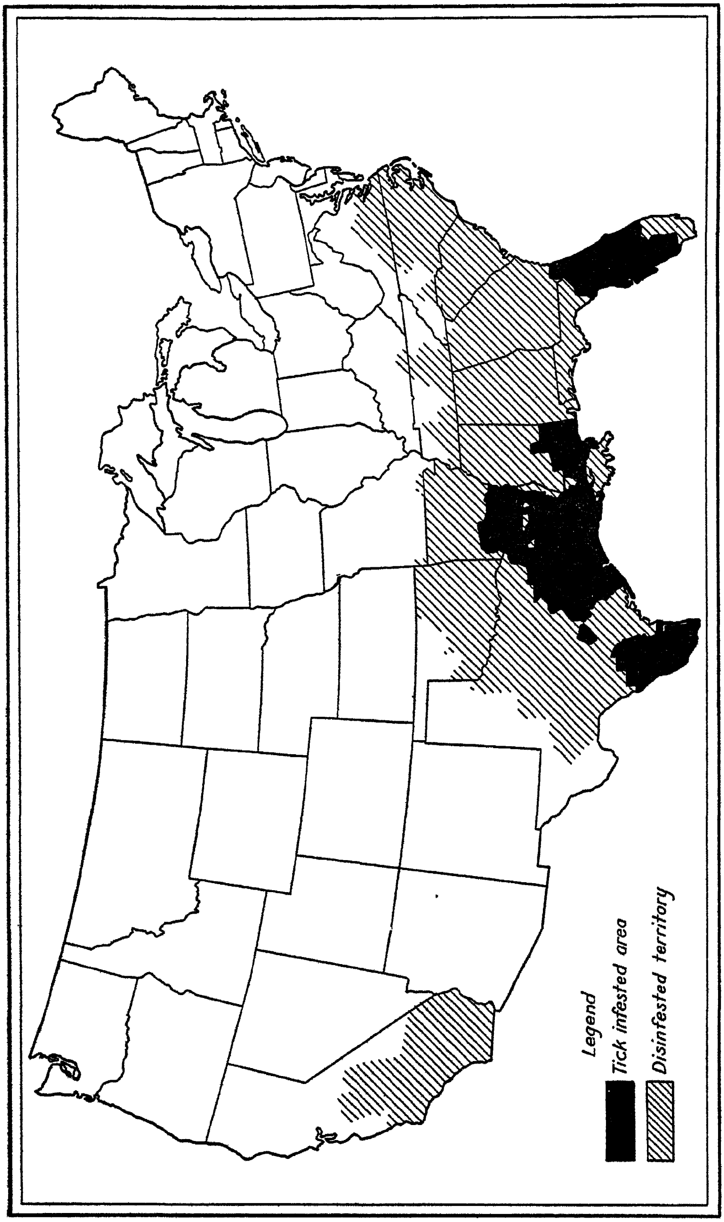

FIG. 77.—Progress in tick eradication in the United States. (1906–1929.)

In order to assure complete safety the cattle are again isolated for 16 days in a clean enclosure and their temperatures controlled as before. After this period they can be admitted to tick-free pastures. Cattle must, for a period of 14 months, be kept away from the pastures which may have become tick infested. Such pastures may, during this period, be used by other animals upon which the ticks present may then "clean" themselves.

Tick-infested animals, carriers of piroplasmae, must not be introduced in disease-free territory without previous disinfestation. When susceptible animals are to be imported in regions where the piroplasmoses are a constant hazard, the selection of young individuals is to be preferred, and the cooler or the dry season of the year is to be chosen as the time of their introduction into their new environment. . Under these conditions the risk of fatal infection may be mitigated, either as it may follow tick infestation or protective inoculation. Heavy tick infestation must always be prevented in the case of such imported animals.

Protective Inoculation.—Relatively soon after the nature and cause of bovine piroplasmosis became better understood and after it became apparent that the resistance to tick-borne infection manifested by animals reared in the regions where the disease occurs enzootically was not inherent, but acquired early in life, attempts were made to utilize the fact in order to assure safety for susceptible animals to be introduced in territory where the malady constitutes a hazard. It was indeed demonstrated that a marked resistance could be induced by artificial modes of infection. As has already been shown, the resistance to the piroplasmoses is never an absolute one; it appears to be dependent on the presence of piroplasmae in the animals concerned.

This fact should not be overlooked, because animals subjected to protective inoculation remain carriers of piroplasmae and are thus able to infect ticks by which the infection may be passed on to susceptible animals. Recognition of this fact has even prompted the proposal that the inoculation be prohibited altogether.

When it is realized that protective inoculation only has its place in regions enzootically infected or in connection with susceptible animals to be imported into such territory, the risk involved cannot, after all, be a very considerable one. Furthermore, the protective inoculation of susceptible animals is the only method of prophylactic value applicable in areas where systematic tick eradication cannot be undertaken. As yet there are many such places.

The method has its widest application in the prophylaxis of Texas fever. Protective inoculation against this disease has been attempted by various methods. One of the earliest efforts consisted of the subcutaneous injection of the diluted paste obtained by the crushing of engorged ticks into the animals to be protected. About the same time Connaway and Francis endeavored to secure a mild form of the malady and subsequent protection against superinfection by means of a restricted number of the infected larvae or nymphs of *Margoropus annulatus,* placed upon the skin of the animals to be treated.

Mohler supplied the following directions for protective inoculation by means of ticks. From 25 to 50 seed ticks are placed upon the young animals to be treated. In about 10 days the latter will show a rise of temperature, indicating actual infection by piroplasmae. When such a subject has entirely recovered from this initial and transitory illness the tick infestation is repeated with twice the number of ticks, in order to further increase the resistance so that tick infestation at pasture may be endured with safety.

The ticks needed in this procedure are secured by placing mature female ticks in a common fruit jar, among some dirt and leaves, and keeping them in a warm place. The ticks will oviposit, and in due course of time the larvae will develop which can then be used for the inoculations.

The tick method is accompanied by some hazard as it does not permit the control of the number of piroplasmae to be thus inoculated into the host animal. Apparently this risk is to a less extent associated with the injection of blood of resistant carrier animals, and hence this method has gained more favor in sanitary practice.

Kolle and Schütz and others propose the following inoculation technique: A healthy, vigorous calf is injected with the blood of a bovine animal which recovered from the disease. It readily surmounts the infection and after a lapse of 3 months its blood has become suitable for inoculation purposes. It is bled from the jugular vein and the blood is defibrinated under sterile conditions and subsequently injected in doses of 3 c.c. into the animals to be treated. This amount has also been approved by North American and Australian investigators.

In the prophylactic inoculation against the South American "tristeza," Lignières makes a first intravenous injection with blood in which the parasites are very numerous and which was stored for 30 days at temperatures of 5 to 8° C. Ten days later, a subcutaneous

inoculation is made with blood which was similarly treated, but for 2 weeks only. Finally the animals are subjected to a third injection of 1 c.c. of blood containing *Babesia argentina*, by him regarded as a distinct species.

According to de Blieck, who observed the practice of preventive inoculation in Australia, young animals artificially infected are used as blood donors from 6 to 10 weeks after their recovery. The blood is collected in a citrate solution in order to prevent its clotting, and it remains good for a considerable period. It is injected in the animals to be treated in doses of 3 to 5 c.c. In some cases 10 c.c. has been recommended. For a herd of 10,000 cattle 4 donors are deemed sufficient to supply the blood required.

As a rule, the reactions which follow the injections are well supported by the animals treated, but an inoculation loss of 1.5 to 2 per cent must be reckoned with. As in naturally infected animals the losses amount to 50 to 90 per cent, the hazard associated with the treatment seems negligible. Since the discovery of trypanblue as a specific in the piroplasmoses the inoculation losses have been materially reduced.

Such losses are ascribed to the premature use of blood donors with too many parasites in the blood, to the inoculation of animals already infected, to the exposure to extraordinary hardships, to the results of excessive exertion and to the premature exposure to heavy tick infestation. In connection with the latter, one should realize that at least 6 weeks must elapse after the inoculation before the treated animals are prepared to resist a severe exposure to natural infection.

The reaction induced by the protective inoculation must be controlled by temperature measurements which may be supplemented by the microscopic examination of blood smears. In the more severe reactions (temperatures of 104.5 to 105° F.), when too many parasites are found in the blood or with the appearance of hemoglobinuria, trypanblue (100 c.c. of a 1 per cent solution) must be injected intravenously or subcutaneously.

It should also be remembered that not all the inoculated animals develop a reaction. The latter apparently is a prerequisite to successful results, and the animals which fail to show it remain susceptible to field infection. In such cases the inoculation must be repeated with the blood of another donor, containing either more or more virulent parasites.

All observers are agreed that the coldest season is the most suit-

able for inoculation practices, and that young animals less than a year old can be treated with the maximum degree of safety. The inoculation of old or pregnant animals is hazardous; they should be excluded from the treatment.

Concerning anaplasmosis which so frequently is co-existent with *Babesia* infection there is no great volume of evidence by which the value of protective inoculation can be accurately estimated. Lignières reported some apparent success by the use of an anaplasmosis virus which had become attenuated by several passages through sheep. Chambers and Smith recommend the inocluation of young, lean animals with 10 c.c. of citrated blood containing *Babesia bigemina* and *Anaplasma centrale.* Two weeks later the same animals receive another injection of 4 to 6 c.c. of blood containing *Babesia bigemina* and *Anaplasma marginale,* originating in the region of ultimate destination.

Good results were also obtained by Theiler from the simultaneous inoculation of 5 c.c. of blood containing *Babesia bigemina* and 5 c.c. of blood containing *Anaplasma centrale.* In the event of the *Babesia* infection causing too severe a reaction he recommends trypanblue treatment.

It was shown to be possible to protect horses against piroplasmosis by means of inoculations with the virulent blood of carrier animals. Young animals, as a rule, tolerate the injections quite well, but in older ones the treatment is more hazardous. The resistance endures for about a year, and it is suggested to expose the treated animals to tick infestation within this period in order to maintain the resistance.

Theiler found that a piroplasma strain of the ass, which had made several passages through animals of this species, when injected into susceptible horses, caused a characteristic reaction which was accompanied by the appearance of the parasites in the blood and from which the subjects recovered. It was suggested that horses to be imported into infected areas be treated with the blood of asses of at least the fourth passage. Asses used as blood donors must be kept stabled in order to prevent undesirable changes of virulence as the result of a tick infestation.

The protective inoculation of sheep against *Babesia* infection may be attempted by methods similar to those employed against Texas fever.

Protective inoculation against coast fever appears to be possible, although, on the whole, it does not seem to succeed as well as in the

Babesia infections. Experience has showed, however, that the inoculation can be undertaken with a prospect of securing the desired resistance in more than half of the animals treated.

The material injected consists of the pulp of the spleen and lymph nodes, aseptically collected from cattle, sick with coast fever, about 2 weeks after the initial rise of temperature. The material is suspended in a physiologic salt solution or in a peptone solution, of which 15 c.c. are injected intravenously.

The treated animals must be kept away from tick-infested pastures for at least 2 weeks. Inoculation losses as high as 25 per cent have, however, been reported, and the resistance secured is not always an absolute one. Thus, after all, certain hazards have to be reckoned with.

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CHAPTER XLIX

THE TRYPANOSOMOSES

UNDER the name trypanosomosis are included a group of maladies having as their etiologic factors protozoan blood parasites belonging to the genus *Trypanosoma* of the family Trypanosomidae. The genus contains many species, not all pathogenic, to which various animal species serve as hosts. Of the trypanosomoses only some of the more important ones can here be considered.

The trypanosomoses, with one notable exception, are diseases peculiar to tropical and subtropical regions, and such disorders as ngana, surra, mal de caderas and others closely related to them are to be found exclusively in the warmer countries; dourine, transmitted in a manner differing from that of the others, is more cosmopolitan in its distribution.

Ngana is peculiar to various parts of tropical Africa. Surra has its principal area of distribution in southeastern Asia, including British India, the adjacent parts of China, Burma, Indochina, Tonkin, the Philippine Islands, Java and Ceylon. It also occurs in northeastern Africa. Surra was introduced into Australia and the United States, but was successfully eradicated before it could gain a permanent foothold in these continents. The mal de caderas of South America has its principal foci in Brazil, Argentina, Bolivia and Paraguay. Dourine is common in northern Africa and has also been observed in South Africa where it is spoken of as "Slapziekte." Its area of distribution includes Asia Minor, Syria, Persia, India, Java and Siberia, and several European countries such as Russia, Germany, Hungary, France, Italy, Spain and others have witnessed the malady either as controllable outbreaks or established in more or less permanent foci. The disease has also appeared on the North American continent where Canada and the United States have had to cope with it on more than one occasion.

Evidence has been brought to light which indicates that ngana was not unknown in the Egypt of three or four thousand years ago, and that its inhabitants, even at that time, already had a more or

less clear notion of the part played by flies in its transmission. The first account of the malady in modern times was rendered in 1857 by Livingston, who described it with clearness and also mentioned the etiologic relationship of the tsetse fly. In 1894 Bruce definitely described the causative trypanosome and rendered experimental proof of the part played by the flies in transmission.

Ngana commonly runs a chronic course but is also seen in a more acute form. It is marked by a maximum mortality in horses, asses and dogs, but in other domestic animals recoveries are more frequent.

Clinically the disorder is marked by intermittent fever, progressive anemia, edematous swellings of the subcutis and terminal exhaustion. Of the after-death appearances, a great waste of body substance, anemia, capillary hemorrhages of the serosa, the gastro-intestinal mucosae, the kidneys and the bladder, as well as enlargement of the spleen and lymph nodes are the most conspicuous.

In the course of the last four decades the ngana area of Africa has become more restricted and the more southern part of the continent has become relieved of its incubus. This appears to be associated with the gradual disappearance of the vector fly attributed to various causes. Among these, recognition is given to the withdrawal northward of the large game animals, a very important source of food for flies. That the spread of cattle plague during the epizootic of 1896–97 to the game animals and its consequent extermination over large areas contributed to the disappearance of ngana is quite generally accepted. The advance of the pioneer, the beginning of agricultural exploitation and the general amelioration of the land must also be credited with a decided influence on the evolution of this interesting ecologic phenomenon.

Surra, long known in India, was first studied by Evans, who in 1880 showed the malady to be caused by the trypanosome which now bears his name. The disease is clinically marked by an intermittent fever, urticarial eruptions, petechiae of the visible mucosae, edema of the subcutis, muscular atony, anemia, progressive loss of flesh and cachexia. In camels the disorder may be accompanied by the development of voluminous abscesses.

The post-mortem findings in surra include tumefaction of the spleen, lymph-node enlargements and capillary hemorrhages in various parts; occasionally ulcerations of the oral and gastric mucosae are encountered.

Surra frequently runs a chronic course, but not uncommonly 1 to 2 months elapse between the first manifestation and its fatal termi-

nation. In camels, surra may be marked by a very chronic course, and in these animals it may persist for as long as 3 years.

The mortality of surra in horses, camels, elephants and dogs commonly approaches 100 per cent of the animals affected although a death-rate of 25 to 80 per cent has been reported. Buffaloes and zebus sicken rarely and then but slightly. These animals, nevertheless, are frequently invaded by the parasites.

The South American equine disorder, mal de caderas (occasionally also observed in dogs), was shown by Elmassian in 1901 to be caused by a trypanosome. The malady is characterized by intermittent febrile attacks, rapidly followed by a progressive loss of body weight. The hair coat becomes staring, there is cardiac impairment and evidence of severe nephritis, resulting in the appearance of blood in the urine. In some cases an annoying, dry cough develops. Edematous enlargement of the lower parts of the body and the extremities is commonly observed. Perhaps the most conspicuous symptom is the extreme weakness of the hind quarters from which the popular name is derived.

The more acute cases terminate fatally in about 1 month; the chronic cases may linger for 4 to 6 months. The mortality is rarely less than 100 per cent of the animals involved. Autopsy reveals a marked degree of emaciation, enlargement of the liver, spleen and lymph nodes. There is a sero-fibrinous exudate in the various serous sacks. The kidneys are involved in a hemorrhagic nephritis with grave parenchymatous changes.

Dourine, which under natural conditions is observed in the solipeds only, first engaged the attention of veterinarians and horse breeders toward the latter part of the eighteenth and during the earlier decades of the nineteenth centuries. Its transmission by copulation (maladie du coit) was early recognized. The causative trypanosome was first seen by Rouguet in 1894.

Dourine is essentially a chronic disorder, although a more acute course has been observed. In stallions it manifests itself by an initial edema of the sheath which gradually is extended to the scrotum and the inguinal region. Infiltration of the penis declares itself, and the regional lymph nodes become enlarged. In the mare the earlier symptoms are less conspicuous, consisting of swelling of the vulva and the adjacent parts, and congestion of the vaginal mucosa, accompanied by a sticky, mucous discharge.

Fever is usually present, but the temperatures do not run very high. In a later phase of the malady small patches of the skin are

raised above the surface. They are known as "plaques" and are somewhat transitory in character. The affected animals lose weight and show marked weakness especially expressed by a dragging gait. There may be ocular involvement, and enlargements of the lymph nodes are commonly observed. Articular and tendovaginal synovites may be in evidence and pregnant mares are apt to abort.

In the latter phases of the disease a profound anemia develops, and paralysis, often paraplegic in character, is a common phenomenon. Cutaneous depigmentation about the perineum, the anus and the mammae is a characteristic symptom which also may be observed in other parts of the body.

The mortality in dourine apparently varies in accordance with locality, ranging between 20 and 80 per cent. Recoveries have been observed, although the apparently recovered cases are apt to sustain exacerbations of the disease or remain infective. Many such cases endure for years.

The post-mortem appearances of animals which succumbed to the more acute forms of the malady include enlargement of the spleen and lymph nodes as well as hyperemia of the liver and kidneys. After the more chronic evolution of the disorder the carcasses show emaciation, anemia, enlargement of the lymph nodes, perivascular infiltration and a marked involvement of the central and peripheral nerve tissues, often indicative of a polyneuritis.

The trypanosomoses mentioned above, as well as certain others not here considered, constitute formidable sources of loss among many species of the domestic animals. Dourine has proved itself to be a most serious incubus on horse-breeding operations in certain districts. Under certain conditions of agricultural practice, it could be readily eradicated, but great difficulties may be encountered in territories where horse stock is maintained under conditions of semi-domestication.

Surra has, perhaps always, been a source of serious and ever-recurring losses; ngana has, in certain parts of tropical Africa, made the pursuit of animal husbandry practically impossible, and there, also, it constitutes a very potent barrier to the use of animals in travel and transportation.

Epizootics of mal de caderas in various parts of South America have, from time to time, been extremely disastrous to the equine population. Lecler, cited by Knuth and du Toit, relates how, of one regiment, 500 of 600 horses died of the malady in the period June to November.

Host Species.—A considerable number of animal species, cold-blooded as well as warm-blooded ones, may serve as hosts to many specifically distinct trypanosomes. Aside from the four trypanosomes here specifically mentioned, there are others more or less important as problems in livestock sanitation and preventive medicine. They are: Parangana (*Tryp. congolense*) of horses and other livestock; Souma (*Tryp. vivax* and *Tryp. cazalboui*) of ruminants and solipeds; Mbori (*Tryp. evansi* var. *mbori.*), and El debab (*Tryp. soudanense*) of camels and horses; Baleri (*Tryp. pecaudi*) and a malady caused by *Tryp. dimorphon* in all livestock; Murrina (*Tryp. hippicum*) and Derrengadera (*Tryp. venezuelense*) of horses and mules; a trypanosomosis of cattle, horses, sheep and goats caused by *Tryp. nanum.*

The principal trypanosomoses of man are sleeping sickness (*Tryp. gambiense*), Rhodesia fever (*Tryp. rhodesiense*) and Chagas disease (*Schizotrypanum cruzi*).

Of the better-known and highly important trypanosomoses, ngana (*Tryp. bruci*) has, under natural conditions, been observed in horses and other solipeds, buffaloes, cattle, sheep, goats, swine, dogs, several species of antelopes and possibly also among wild carnivora, camels and elephants.

Dogs and swine of European origin are very susceptible, but horses, cattle and breeds of dogs native to the areas involved are somewhat less liable to the infection. Among the native sheep, goats, wild swine and the large game animals of the country, ngana is less common, even if some of these species may become carriers of the parasites.

Artificial infection with the ngana trypanosome is possible in all species which contract the disease under natural conditions and practically succeeds readily in nearly all the warm-blooded animals used in experiments, such as cavias, rabbits, rats, mice, cats and monkeys. On the other hand, birds can be infected only with difficulty, if at all.

Under natural conditions, dourine (*Tryp. equiperdum*) occurs only in equines, but can be induced with more or less facility in sheep, goats, dogs, cats, rabbits, cavias, rats, mice and monkeys. The specific trypanosomes have also been transmitted to fowls, but caused no manifest illness in these subjects. It is obvious that horses, asses and mules are also liable to artificial infection.

The horse and, in a less degree, asses and mules are most susceptible to mal de caderas (*Tryp. equinum*). The causative parasite can be artificially transmitted also to dogs, cats, rabbits, cavias, mice,

rats, capybaras (carpinchos), monkeys and other animals. Cattle, sheep, goats and swine are quite refractive, and even though the parasites may appear in their blood as a result of inoculation, they do not sicken.. Transmission to birds seems to be difficult and uncertain in result.

To surra (*Tryp. evansi*), horses and mules are the most susceptible of all animals, although cats and imported dogs are also highly liable to this trypanosomosis. The native canines, on the other hand, are reputed to be more refractive. The malady is also apt to be fatal to camels and elephants, whereas in cattle, buffaloes, sheep and goats a more benign course is usually observed. Swine appear to be exempt from manifest surra.

With the exception of birds, artificial infection readily succeeds in most warm-blooded animals, including the equines, cattle, sheep, goats, dogs, cats, elephants, camels, buffaloes, as well as the small laboratory animals.

The Pathogenic Trypanosomes.—The parasitic causes of the trypanosomoses are flagellates of the family Trypanosomidae, belonging to the genus *Trypanosoma.* They occur in the blood of their hosts as fusiform cells, provided with a flagellum and an undulating membrane by which they propel themselves.

The pathogenic trypanosomes may be found in variable numbers in the blood of their mammalian hosts, in the fluid obtainable from the edematous swellings and from the urticarial lesions of the skin. The parasite of dourine may also be seen in the "plaques" and in the genito-urinary mucus.

The number of parasites to be encountered varies greatly in accordance with the specific peculiarities as well as with the status of the affected host. Often they are very scarce in dourine; in the other trypanosomes they are always most numerous during the febrile exacerbations and in the more acute forms of these disorders. In surra the number of trypanosomes rarely exceeds 400 per cubic millimeter, although in certain cases many thousands were found to be present in this quantity of blood.

In the blood of the vertebrate hosts the trypanosomes multiply by longitudinal fission in two equal parts, each of which retains the morphological aspect of the parent cell. Another type of reproduction has been described in which the parasite before division assumes a spherical form, during which the flagellum and undulating membrane may be wholly or partially lost.

The trypanosomes transmitted by vectors apparently undergo a

development resulting in forms resembling the *Crithidia,* a genus closely related to the trypanosomas.

In the case of *Tryp. equiperdum* there is no vector; in others the vectors serve merely in a mechanical manner, but in many, the parasites are subject to a further development, corresponding to that of the *Crithidia.* In this connection, Wenyon states that although the greater number of trypanosomes are known only as they inhabit the blood of vertebrate hosts, it is safe to assume that, with the possible exception of the parasite of dourine, there exists an invertebrate host for all the others.

Outside the body of the host animal, the trypanosomes are very fragile and do not long survive their removal from the same. In tapwater or distilled water the cells swell, become deformed, rapidly die and disintegrate.

Most of the trypanosomes are very sensitive to heat and succumb when the ambient temperature exceeds 40° C. They survive longer at lower temperatures, but whatever the temperature they never live beyond a 5- or 6-day period. The parasites are rapidly destroyed by drying.

Modes and Vehicles of Infection.—Three factors play a part in the propagation of most of the trypanosomes, namely: the infected animal as the incubator of the parasites; the vector flies as the vehicles and instruments in their transmission, and a new host as the soil for new generations of the flagellates to develop in.

The infected animal may be suffering from actual disease or merely be a healthy carrier of the trypanosomes. In either case it constitutes a source of parasites upon which the dissemination of the malady depends. The sick animals are most infective during the acute exacerbations of the disorder, during which a maximum number of parasites is apt to be present in the blood. Latently infected animals, always carriers of trypanosomes, may continue as infection reservoirs for many years.

The animals infect or contaminate the vector flies feeding on their blood, and these, by attacking new animals, are enabled to transmit the disease. Only in the case of *Tryp. equiperdum* does transmission take place by direct contact, and under natural conditions a vector plays no part.

Experimentally, infection by trypanosomes is readily achieved by subcutaneous, intravenous, intraperitoneal and intramuscular inoculations. Muijzert showed that animals could be infected with certain trypanosomes by placing them upon the uninjured mucosa of the eye

and the vagina, provided that the blood used as inoculum contained a large number of the parasites. If only a few were available, a general infection could not be realized. Vrijburg also succeeded in infecting a horse with surra in a similar manner.

Less readily may a positive infection be secured by the application of blood containing pathogenic trypanosomes to fresh wounds. Intra-uterine infection also appears to be possible as the trypanosomes concerned have been found to be present in the aborted fetus. As a general rule, however, the young born of an infected dam are, according to Wenyon, not infected even if they are endowed with the specific susceptibility peculiar to the parent stock.

The milk of infected animals may contain the parasites; positive inoculation results have been obtained with *Tryp. evansi, Tryp. brucei, Tryp. Gambiense* and *Tryp. rhodesiense*. The parasite causing dourine has been occasionally found in the milk. However, it does not appear that the mammary secretion plays an important part in the natural transmission of the trypanosomoses. For this, with the exception of dourine, the agency of biting flies is required. Flies of the genera *Glossina, Tabanus* and *Stomoxys* are prominent as vectors.

In the course of the infection the parasites periodically appear in the blood in great numbers, giving rise to the exacerbations peculiar to these maladies.

The mode of pathogenesis is not fully understood, but there is warrant for the belief that toxic substances destructive to the erythrocytes and disturbing to the general metabolism must be reckoned with in this connection.

In the propagation of surra, aside from animals actually sick with the disease, cattle, including zebus, as well as camels and certain wild animals serve as the normal carriers and infection sources; it is not impossible that rats and swine may play a similar part.

The thorough work of Mitzmain, Nieschulz and others, confirmed by numerous workers, showed that flies of the genus *Tabanus* must be regarded as the principal vectors of surra. The tabanids experimentally shown to be capable of transmitting *Tryp. evansi* include *T. striatus, T. partitus, T. vagus, T. fumifer, T. minimus, T. albimedes, T. nemocallosus, T. rubidus, T. hilaris, T. stantoni, T. ceylonicus, T. bacallosis, T. virgo, T. ditaeniatus, T. immanis, T. flavivitalis, T. brunipes, T. tropicus, T. atratis.*

The prominence of this genus in the transmission of surra is warrant for the belief that wherever any of the Tabanidae abound the

dissemination of the malady becomes possible if animals, carriers of *Tryp. evansi,* are introduced in the areas concerned.

In addition to the tabanid flies as the more conspicuous vectors, transmission may also be effected by *Stomoxys calcitrans, Aedes aegypti, Haematopota pluvialis* and species of *Chrysops.*

Carnivora may become infected with surra through lesions of the skin and mucous membranes while devouring fresh carcasses of animals that have died of the disease.

The incubation periods of surra range between 4 to 13 days in the horse.

The infection sources of ngana include animals involved in the disease, the domestic animals which have become carriers as well as the large game animals of the regions where the vector flies abound. Game animals are latent carriers, and, no doubt, they constitute an important reservoir of infection. They are a source of the food supply of the flies. They may not be entirely indispensable in the propagation of the malady if other carriers are available.

The tsetse flies are the active vectors of ngana, *Glossina morsitans* being the principal offender, while *Gl. palpalis, Gl. tachinoides, Gl. palpis* and *Gl. pallidepes* may also serve in a like manner.

The trypanosomes ingested by the tsetse with the blood of the host animals give rise to infection only after a lapse of time of variable duration. This fact, in a measure, supports the views that the flies not merely act in a mechanical manner but may be regarded as functioning also as intermediary hosts. It was shown that 15 to 18 days must elapse after the infective blood meal before *Gl. palpalis* can transmit the disease; 11 days are required in the case of *Gl. morsitans.* Tsetse flies once infected remain infective during their lifetime. Transmission of ngana by caught and artificially infected flies but rarely succeeds.

Species of the genera *Stomoxys, Lyperosia, Tabanus* and *Haematopota* may also act as mechanical vectors and are able to play an active part when present in large numbers in enclosures where many animals are crowded together.

The incubation periods of ngana are 3 to 15 days for horses and 4 to 15 days for cattle.

The mode of transmission of mal de caderas is not known with certainty. Vector flies are suspected, and in this connection mention is made of *Stomoxys brava,* tabanids and mosquitoes. Lignières suspects that, among dogs, fleas may be factors in transmission, and species of *Chrysops* are mentioned by other observers.

Outbreaks of mal de caderas have been noted to be synchronous with epizootic sickness among the rodents, carpinchos or capybaras (*Hydrochoeres capibara*), and these animals may constitute a natural reservoir for *Tryp. equinum.*

After artificial infection, horses sicken 4 to 8 days after the inoculation.

Dourine, under natural conditions, is transmitted only by sexual contact, although insect influences may, in exceptional cases, have to be reckoned with. *Stomoxys* has been suspected, and transmission among rats by fleas has been experimentally achieved. It remains very doubtful, however, that vectors play a part in a disorder in which the number of parasites in the blood is as small as they are in the case of dourine.

Tryp. equiperdum can penetrate the intact mucosa, and positive infections have been produced by dropping virulent material into the conjunctival sack. Horses latently infected may transmit the disease, and the virulence of the trypanosomes becomes exalted in the course of repeated passages from animal to animal.

Sponges used in the cleansing of the genitalia of infected animals may serve as possible vehicles for the parasites and be instrumental in transmission.

The period of incubation after an infective copulation ranges from 6 or 8 days to a month. On the whole mares become more rapidly infected and sicken more severely than stallions.

Factors Favoring Infection.—The incidence of the vector-borne trypanosomes is especially determined by the prevalence of the flies, carriers of the parasites, as well as by the presence of animals which, in a state of unimpaired health, serve as hosts to the trypanosomes. Topographic and climatic conditions favorable to the development of the vector flies in a more indirect manner supply influences tending to affect morbidity.

In the case of surra, it could be shown that the disease is most apt to declare itself in certain localities, or "surra zones" separate from one another by areas relatively free from the malady. Such zones commonly include low places, subject to periodic inundations and covered by tall grasses and brush, environments particularly adapted as breeding grounds for the Tabanidae. For the same reason surra tends to show a seasonal incidence, the rainy season favoring the development of the flies.

In addition to an environment favorable to fly propagation, the incidence of the trypanosomoses is necessarily influenced by the fact

that the vectors have access to animals the blood of which contains the causative parasites.

Thus the regional distribution of tsetse species of Africa in so-called fly-belts is supplemented by the supply of trypanosomes available in the large game animals of the regions concerned. A similar combination may possibly be a factor also in the dissemination of mal de caderas, the etiologic factors of which have apparently an infection reservoir in the capybaras which inhabit the territory where the malady is enzootic.

The species of *Glossina* are in a large measure dependent on the larger mammals for their food supply; with the disappearance of these animals, the flies are also apt to diminish and to vanish unless supplanted by other suitable species upon which to feed.

The morbidity of the trypanosomes depending on flies for their transmission is obviously influenced also by the specific susceptibility of the livestock of affected areas. In this, there are variations, and, on the whole, animals native to the areas where a trypanosomosis exists enzootically are more resistant to infection than those introduced by importation from disease-free countries.

That the more resistant animals are, nevertheless, liable to become latently infected and to serve as reservoirs of the infection, cannot fail to exercise a potent influence on epizootology and may be instrumental in rendering infection foci more enduring.

Prophylaxis.—One of the principal tasks of preventive veterinary medicine with regard to the trypanosomoses is to erect barriers against their introduction into territories and countries which thus far have escaped invasion. All importation of animals from infected regions should either be prohibited or their status as possible carriers of pathogenic trypanosomes must be severely challenged. If such animals must be introduced they should be kept in fly-proof segregation for a period of sufficient length to make possible repeated blood examinations, if need be, supported by diagnostic inoculations into laboratory animals. Even wild animals destined for menageries and zoological collections should not escape close scrutiny. Animals originating in territory adjacent to areas in which any of the trypanosomes occur enzootically should likewise be looked upon with suspicion.

These measures pertain particularly to countries of which the arthropod fauna includes species capable of serving as vectors for the parasites. The danger of introducing ngana in regions where

Glossina species do not occur is not greatly to be feared, although possible new adaptations must not be left out of consideration.

If, in spite of sanitary police regulations, or because of their absence or inadequacy, a trypanosomosis declares itself in clean territory, there should be no delay, after a positive diagnosis has been established, in placing the areas affected under quarantine. All traffic of livestock, in either direction, should cease unless the animals are destined for immediate slaughter.

If means are available to permit the destruction of the animals involved and for the compensation of their owners, these measures must be given serious consideration as the most economical method of preventing what otherwise may become an intolerable incubus on animal husbandry.

In areas where the fly-borne trypanosomoses are enzootic, prevention may be exceedingly difficult, largely because of the nature of their topography, vegetation and the type of animal husbandry practiced in the most seriously involved territories. In such regions, virus carriers are apt to be numerous among livestock as well as among wild animals, and vector flies are commonly present in great abundance. The latter always present the major part of the problem, and in all attempts at prophylaxis they must be given first consideration.

In certain instances disinfestation methods (see chapter on Disinfestation and Disinfestants) may be helpful, but in the face of the conditions frequently imposed by an unsubdued nature their application may be impossible.

The avoidance of tsetse territory areas by livestock is, no doubt, of value, and in the case of surra the breeding places of the prevalent tabanids, once they have become known, are likewise to be shunned. The removal of horse stock to higher ground, away from the low areas, during the rainy season, has been helpful in the prevention of mal de caderas.

Amelioration of the environment by the removal of brush and other rank vegetation and the drainage of the land can be regarded as useful when faced by any of the vector-borne trypanosomoses. However, as such measures require application to extensive areas, their cost usually is prohibitive.

The gradual advance of an orderly type of agriculture, which utilizes all the land and which causes the withdrawal of parasitized wild animals, probably will, in time, prove to be the most potent factor in the ultimate conquest of tsetse territory. The advent of power

tillage may come to have a prominent share in making a profitable animal husbandry possible in regions where it cannot thrive at this time.

Under certain circumstances the destruction of animals disclosed to be infection carriers may be indicated and worthy of consideration. The prompt slaughter of animals sick with any of the maladies belonging to the group under consideration, or at least their removal from further fly contacts, is certainly a measure to be approved.

Against dourine a more radical and exact procedure of prophylaxis is possible of application. As in the other trypanosomoses, the introduction of infected horses into a disease-free territory should be prevented by measures similar to those effective against the former.

After the malady has once established itself in an equine population, efforts should at once be made to eradicate it by all available means. The absence of the vector problem and the well-known fact that the disease is practically always transmitted by sexual contact renders dourine more amenable to livestock sanitary control than any of the other trypanosomoses. In the districts concerned, all breeding operations should be suspended as long as the disorder remains, and all exposed stallions gelded; mares with a history of contact should be branded and kept under surveillance. As the infection of the young by the milk of infected dams seems to be possible, the colts should also be subject to observation.

Such measures may prove to be successful in certain areas, but they may require a long period of supervision and even then may bring disappointment, owing to the fact that infected but not manifestly diseased animals are capable of spreading the infection. Even the castration of stallions may not be an absolute barrier to the spread of infection, because such animals remain capable of copulation for a considerable period after the operation.

For these and other reasons, the more radical procedure of destroying outright all infected animals should be given preference. The discovery of the complement fixation test as a means of recognizing such animals with relative facility became a most potent factor in making the more radical measures possible. In its application, all horses in the regions affected are subjected to the serologic test, and the ones reacting positively are destroyed under livestock sanitary supervision and their owners adequately reimbursed for the damage they thus sustain.

In the United States and Canada, this mode of eradication was eminently successful in regions where prophylaxis was extremely

difficult to achieve, if not utterly impossible, by any other means. The success obtained on the open ranges and Indian territories of these countries is warrant that by this method the eradication of dourine in settled agricultural districts should not be very difficult to accomplish.

However, even when this method of eradication is applied, it remains advisable to suspend breeding operations and continue the castration of stallions on the open ranges; as an additional security, the testing of all animals should be periodically repeated until positive reactions are no longer obtained.

Protection by Chemicals.—As long ago as 1857, Livingston, in a first account of ngana, indicated that a transitory improvement in the affected animals could be obtained by the administration of arsenic. Since the trypanosomoses became the subject of scientific research much attention has been given to efforts in an endeavor to develop methods of specific therapy.

These attempts have thus far not resulted in a dependable, radical method of treatment, but it can be shown that certain chemical substances, in a more or less striking manner, exercise a definite and favorable influence on the course of the maladies concerned. Thus it has been shown that such substances as arsenic, tartar emetic, atoxyl and Bayer 205 (germanin, moranyl, naganol) had a certain specific effect on the trypanosomes present in the blood of the host animals treated. The number of the parasites was reduced and sick animals improved, although a total destruction of the trypanosomes could not be brought about. The latter develop drug-resistant strains and thus become able to maintain themselves in their hosts in spite of the treatment.

Although an absolute "cure" could not be secured with any degree of completeness or constancy, it became apparent that a temporary protection, at least, might be possible, and further investigations brought a volume of evidence of a more or less encouraging nature. Only a small part of this evidence can here be submitted.

Kleine and Fischer experimented with 6 head of small cattle kept in a tsetse pasture. Three of these were made to serve as controls and the other 3 animals received the prophylactic treatment and were respectively given 4, 5 and 6 intravenous injections containing 5 grams of Bayer 205 and 0.75 gram of tartar emetic, at 7-day intervals.

The animal which received the 5 injections remained entirely free of trypanosomes. The subject which received 6 injections showed a few parasites 33 days after the termination of the exposure. The

remaining animal showed in the blood some forms which could be regarded as disintegrated trypanosomes when it was examined 57 days after the last exposure and 40 days after the last injection. All the prophylactically treated animals remained healthy and maintained themselves in an excellent state of nutrition.

Of the three control subjects, one received 4 intravenous injections, each containing 0.75 gram of tartar emetic, at 7-day intervals. This treatment delayed infection in a substantial manner. The other two control animals were not treated and were found to be infected 7 days after leaving the tsetse pasture.

Another observer, Berg, succeeded in keeping cattle on a badly infected farm free from parasites and in a good state of nutrition by semimonthly intravenous injections, each containing 2.5 grams of Bayer 205 and 1 gram of tartar emetic.

Hornby and Burns relate the following observations: Ten bulls were placed in a territory badly infested by tsetse, with the result that 6 of the number were dead within 3 months and none survived longer than 8 months.

An equal number of bulls were placed in the same fly belt, but injected every 2 weeks of the first 5 months with 1 gram of tartar emetic. Only 2 of these animals died within 7 months, and the remaining 8 were in a marketable condition at the end of this period although infected with trypanosomes.

Another 10 bulls similarly exposed and injected every 2 weeks during the first 5 months with a mixture of 2.5 grams of Bayer 205 and 1 gram of tartar emetic. Three of these died within 7 months. Of the survivors one was very sick at the end of that time; the others, though infected, were in a marketable condition.

These authors concluded that, by means of fortnightly injections of tartar emetic, cattle can be kept alive in a fly belt for a number of months without losing much condition, that advantage might be taken of the treatment when moving slaughter animals through a fly belt, but that it is unlikely that oxen, thus treated, could be worked economically within such a belt and that no advantage is obtained when Bayer 205 is added to the tartar emetic.

Ruppert treated mules exposed to tsetse every tenth and eleventh day with 2 grams of a 10 per cent solution of atoxyl subcutaneously and 2 grams of tartar emetic in 25 c.c. of water intravenously and reported that the animals were still fit for service after 6 months. He recommends that the prophylactic treatment should commence before the animals are taken into tsetse territory.

Rodenwalt and Douwes, cited by Zwick and Knuth, recommended that with reference to surra all badly diseased animals are to be destroyed, as they cannot be saved by the use of Bayer 205. All animals in the initial stages may be treated with 5 grams of Bayer 205 per 200 kilogram of body weight or in broken doses of 0.5 gram per 150 to 200 kilogram every 2 days until a total of 10 to 15 grams has been administered.

All recurrent cases are to be destroyed, as further treatment would be useless and there is always danger of developing resistant strains of the trypanosomes. All suspected animals in a given area to receive 1 gram of Bayer 205 per 150 kilograms body weight. The prophylactic injections are to be repeated after 4 weeks in view of the presence of vector flies.

As the prophylactic treatment against mal de caderas, Bayer 205 has given favorable results, and it appears that doses of 2 to 3 grams afford protection for at least a month.

As in the attempts with curative treatment, the prophylactic injections do not bring about the total disappearance of the parasites, and drug-resistant strains may develop and keep the infection alive. From the evidence thus far made available, it appears that a temporary protection may be obtained. This may be helpful in certain specific instances, but whether or not a method useful as a general means of prophylaxis can be developed is as yet uncertain.

Animals used in transportation or butcher stock en route to abattoirs may, however, be safeguarded while passing through fly territory, and this achievement is certainly of a distinct value.

Apparently, immunity against the trypanosomes similar to that which follows certain bacterial infections does not exist even if a superinfection may be difficult. There always remains a latent infection due to a mutual host-parasite adaptation.

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CHAPTER L

COCCIDIOSIS

THE name coccidiosis is applied to a complex of morbid manifestations arising from the presence and vital activities of a number of parasitic protozoan species belonging to the order Coccidia.

Since coccidial disease began to be recognized early in the nineteenth century, it has been found to occur in many countries and in several animal species. Bovine coccidiosis was first recognized as a disorder of economic importance in Switzerland and since then in many of the other European countries, in sections of North America, Africa and other regions. Like the coccidioses of the rabbit and the common fowl, the bovine disease has also acquired a more or less cosmopolitan distribution.

Avian coccidiosis is scattered the world over and plays a prominent part among the causes of death in the younger birds. In young rabbits the malady is one of the chief factors in mortality.

Coccidiosis of sheep is by no means uncommon in this country and has also been reported from England, Italy, France, India, the Sudan and other parts of the Old World. The disease also affects goats, in which animals it has been observed in France, Germany and Africa. Coccidial disease among swine has been described from the Netherlands and Germany and has also occurred in the United States.

The manifestations of coccidiosis in its more common forms are characterized by a more or less persistent diarrhea, bloody feces, emaciation and evidence of septic intoxication. The pathogenic coccidia are intracellular parasites which more commonly find their optimum habitat in the intestinal canal, in organs in direct communication with the latter, in organs more remotely situated as well as in the blood. In the domesticated animals which are subject to coccidiosis the intestinal epithelium becomes more commonly and often exclusively involved.

The bile ducts in some species also supply a site of invasion, and in the rabbit, hepatic lesions arising as a sequel to the latter are an almost constant phenomenon. Hepatic localization is also observed in other host species. Renal coccidiosis occurs in the goose.

The invaded epithelium is ultimately destroyed by the parasites. The extent of the areas involved in the damage so inflicted largely determines the degree of severity of the pathologic process arising from the invasion.

In such animals as cattle, rabbits, swine, dogs and fowls, the parasitic invasion is more or less evenly distributed throughout the extent of the sections of the gut involved, but in others, like sheep and goats, the parasites conglomerate in circumscribed foci, which then appear as light-colored, flat nodules in the superficial layers of the intestinal mucosa.

In bovine coccidiosis the large intestine, especially the rectum, supplies the site of invasion. In rabbits the small intestines, the bile ducts and the liver are particularly involved, and nasal coccidiosis is occasionally observed.

In coccidial disease of the fowl the entire intestinal tract is apt to show evidence of invasion, but in a large proportion of the cases the ceca appear to be the site of choice. Coccidiosis in the sheep and goat more commonly involves the duodenum and jejunum, but, on occasions, the colon, the cecum and even the bile ducts may also be invaded.

In swine the jejunum and ileum are the common intestinal sections where coccidial lesions become localized. In geese the renal epithelium is invaded.

The morbid changes of coccidial disease of the intestine are those of hemorrhagic enteritis. The mischief caused by intestinal coccidiosis can be attributed to disturbance of the intestinal functions in the sections concerned, to the exudation of the body fluids in the denuded areas, to the establishment of ports of entrance for pathogenic bacteria and to the absorption of their toxins or of toxic substances which may be present in the contents of the gut.

The epizootologic features of coccidiosis vary in character. In certain districts or on certain farms coccidiosis of a given species may be enzootic. In rabbits the disease is often epizootic in character and may rapidly exterminate all the animals belonging to the more vulnerable age group.

Bovine coccidiosis may be widely distributed over certain areas, but even there, the morbidity is not always the same. During certain years the disease may be particularly disastrous, whereas in the following year only a very few animals appear to be affected. The cattle disease is commonly described as a pasture infection. Yet it may rage with uncommon severity in feeding yards and stables. The

same epizootologic behavior may be observed in sheep coccidiosis also.

Similar variations are noted in connection with the period during which the disease is most commonly observed. Although often described as a disorder peculiar to the pasture season, winter outbreaks are frequently observed. Roderick, who studied bovine coccidiosis in North Dakota, reports the disease as but rarely occurring during spring and summer, and as becoming a more or less serious problem late in autumn and during the earlier weeks of winter. He says that the appearance of the malady seems to be synchronous with the advent of the more severe winter weather, and he regards this phenomenon as the most striking feature of its epizootology.

In all probability, time and place, *per se,* are less important as epizootologic factors than they are commonly considered to be, and as such they may be more apparent than real. In fowls and rabbits, outbreaks of coccidial disease are apt to occur whenever animals of maximum susceptibility are present in an environment containing a conspicuous amount of coccidia, and probably these factors dominate the epizootology of the disease in other species as well. The influence of other factors, yet unknown, must, however, not be denied.

The mortality rate of coccidiosis is in many species a high one. It is highest in rabbits, in which from 90 to 100 per cent of the sick animals succumb; the losses in chicks occasionally ranging between 50 and 90 per cent, are also quite severe. In cattle, the death-rate from coccidiosis is often reported to range between 2 and 5 per cent. However, Bruce reports a death-rate of 30 per cent in one outbreak and Roderick estimates the losses among affected animals as fluctuating between 10 and 50 per cent.

Losses in sheep and goats may range between 10 and 90 per cent of the animals manifestly affected with coccidiosis. The number of parasites available for invasion and the degree of susceptibility on the part of the host animals may affect mortality as well as morbidity in a dominant fashion.

Host Species.—Coccidial parasitism is widespread in nature; an almost endless number of invertebrates, as well as vertebrates, serve as hosts. Among the domestic animals, coccidia occur in cattle, sheep, goats, swine, dogs, cats, rabbits and poultry. The horse and the ass are apparently the only domesticated species in which coccidia have as yet not been shown to occur.

Some of these animals may serve as host to more than one species of coccidia. On the other hand, there is consensus of opinion that

these parasites are, on the whole, strictly specific in their host relations. So far as it has been possible to determine, it appears to be possible that several bird species are the common hosts to one coccidial species. In addition it should be observed that Andrews pointed out that the dog may become infested by the coccidia peculiar to the cat, and vice versa.

The specific host-parasite relations which apparently prevail in the coccidial infestation of the domestic animals, which render one species refractive to the coccidia of another, is obviously of great importance when coccidiosis becomes a subject of livestock sanitary concern.

The Pathogenic Coccidia.—As has already been pointed out, the host-parasite relations of the coccidia, with only a few exceptions, are strictly specific. Coccidial parasitism in the domestic animals involves the following species: In cattle: *Eimeria zürni* and *E. canadensis.* In sheep: *E. faurei.* In goats: *E. arloingi.* In swine: *E. debliecki.* In rabbits: *E. stiedae* and *E. perforans.* In dogs and cats: *Isospora bigemina, I. rivolta* and *I. felis.* In fowls and turkeys: *E. avium.* In pigeons: *E. pfeifferi.* In geese: *E. truncata.*

The pathogenic coccidia which play a primary part in producing disease in the domestic animals are cytoparasites, motile only when they appear as the fusiform sporozoite, merizoid and microgamete forms. With the exception of these forms, coccidia are ovoid or spherical in shape.

The group is characterized by a complicated process of development and reproduction, which, though not identical for all species, on the whole conforms to the following modes more or less characteristic for the genus *Eimeria.*

Mature oocysts taken into the alimentary canal by a host animal disintegrate in the intestine and liberate the sporozoites which they contain. The latter penetrate the intestinal epithelial cells and there develop into the oval or spherical forms known as schizonts. In the course of growth and development, the nucleus of the schizont undergoes segmentation, and the growing number of daughter nuclei by gathering protoplasm change into small, elongated nucleated bodies, the merozoites.

These, in appearance, resemble the sporozoites already mentioned, and like them seek a new host cell, after the destruction of the original one occupied by the parent schizont. There the merozoites develop into schizonts. This process of schizogony may be repeated several times, the parasites being reproduced at a tremendous rate.

Thus far the reproductive process has been entirely an asexual one, but under conditions not always clearly understood, the merozoites cease to become schizonts and develop into sexual forms after penetrating a new host cell. There they develop into macrogametocytes and microgametocytes. The former changes into a macrogamete (eggs or female element), while the microgametocyte splits into a great number of microgametes or male elements. The latter make contact with a macrogamete and copulate with fecundation as the result.

At the completion of this union of male and female elements, the fertilized macrogamete becomes surrounded by a dense membrane or capsule and is then known as oocyst or enduring form. The oocysts are carried out of the body with the feces; in the extra-corporeal situation they continue further development when conditions of temperature, and moisture are suitable. For the initial phases of this process a sojourn outside the body of the host seems to be necessary. It involves a second asexual cycle of reproduction known as sporogony.

The protoplasm of the oocyst divides into four masses, sporoblasts, each of which assumes a capsule and becomes a sporocyst. Within the latter, by a further division, two sporozoites are formed which are liberated shortly after the introduction of the ripe oocyst into the host animal. They then seek a cell host and thus complete the cycle.

Under suitable conditions, the maturing of the oocyst outside the animal body requires from 2 to 5 days. Immature oocysts are not infective, but they, as well as the sporulated cells, are extremely resistant to external influences. They have been found to retain their viability for not less than a year; toward chemical disinfectants, their resistance exceeds that of most pathogenic microbes.

Sporulation is suspended or delayed by low temperatures and by a lack of moisture and oxygen. The oocysts, however, are not destroyed by freezing, but are speedily killed by exposure to high temperatures.

Modes and Vehicles of Infection.—The oocysts eliminated by animals affected with coccidiosis or by healthy carriers are the forms by which the invasion of a new host is initiated. The part played by healthy carrier hosts must not be under-estimated. Healthy adult animals commonly serve in that capacity, and are not damaged by the parasites in a manner clinically perceptible. Müller found 88 per cent of 42 head of cattle free of lesions to harbor the parasites.

Nöller and Otten and Otten established their presence in 91 per cent of the goats, in 69 per cent of the sheep, in 65 per cent of the swine, in 22 per cent of cattle more than 3 years old and in 54 per cent of the calves, all subjects in good health which they had occasion to examine at Berlin. Similar observations were made by other investigators.

Mother animals commonly incubate the parasites eventually fatal to their young, and old fowls not infrequently constitute formidable infection reservoirs. *Eimeria stiedae* is so widely disseminated that it is not always an easy matter to find rabbits which are not invaded by these parasites.

It seems probable that in the carrier animals schizogony is not entirely suspended, and that a more or less latent infestation is maintained by asexual reproduction. In some of the animals thus parasitized a flare-up of disease may occur which may readily be mistaken for re-infection.

In the healthy carrier host, the parasites have been found to occur in the intestinal epithelium; oocysts, capable of sporulation, can frequently be demonstrated in the feces. Coccidial parasitism without pathologic sequelae may persist for years in a given animal; such hosts often constitute an important factor in outbreaks of coccidiosis among young animals placed in the same environment.

The parasites leave the body of the host in the form of oocysts which in the presence of suitable conditions sporulate and become infective. The ripe oocyst is taken into the body of a new host by means of food and drink contaminated with feces. Wherever such a contamination can take place, transmission of the parasites and of the disease caused by them is apt to occur.

Contact with sporulated oocysts may come about by means of the surface water of pools or swampy areas or by forage plants grown on or near such places.

Hence, coccidiosis is often described as a pasture disease. It is, however, by no means exclusively so, as formidable outbreaks in stables, corrals or feeding yards are often observed. In fact, wherever infective fecal matter can find its way to food and water a coccidiosis hazard is always present. Owing to the resistance of the oocyst to external influences, this hazard may persist as long as a year after the last carrier animal has been removed.

Exposure to coccidial invasion may occur in any type of environment where the host of coccidia is present. The rabbit cage with its accumulation of grossly befouled, moist bedding, as well as the poul-

try yard with its heavily polluted soil, not uncommonly are the scenes of deadly outbreaks among the younger occupants.

Coccidiosis is always of alimentary origin. The ingestion of sporulated oocysts by a specific host is rapidly followed by the disintegration of the former by the digestive enzymes of the latter. The sporozoites thus liberated immediately invade these cell hosts, and, depending on the number of the invaders, the susceptible sections of the intestinal tube may have to sustain a massive assault, possibly followed by a production of oocysts, provided that the host survives the invasion of the coccidia asexually reproduced.

The period of incubation in the coccidioses, at best very difficult to establish, is stated to be about 3 weeks, although instances are recorded when symptoms appeared in 6 to 8 days after the parasitic invasion could have taken place.

The possibility of secondary infection sources is mentioned in literature. They are supplied by animals not themselves hosts of the coccidia concerned, which may come in contact with infective fecal matter, such as rats, mice, wild birds, flies and the larvae of insects. That the rat may serve as a mechanical carrier for rabbit coccidia has been demonstrated by experiment.

Factors Favoring Infection.—Among the factors favorable to the occurrence of coccidiosis two must be regarded as fundamental, namely: the abundance of sporulated oocysts in a given environment, and the presence therein of animals showing a maximum degree of susceptibility. Without these, coccidial disease would be relatively rare. The influence of season and all other predisposing factors are merely of a supplementary nature.

However, there can be no doubt that low pastures and the presence of surface moisture are very favorable to the sporulation of the oocysts and that this process is further enhanced by the higher temperatures prevailing during summer and early autumn. Thus, it is not to be wondered at that coccidiosis of cattle, sheep, goats and swine is so commonly described as a pasture disease.

In the estimation of the apparent part played by season and locality, consideration must also be given to the fact that during the pasture season the animals exposed usually include a maximum number of those belonging to the age groups endowed with the highest degree of susceptibility.

Coccidiosis always claims most of its victims among young animals. Cattle from 6 months to 2 years of age, lambs 2 to 3 months old, rabbits 4 to 6 weeks old and chicks up to the age of 3 to 8 weeks are par-

ticularly endangered in environments where a conspicuous number of oocysts could sporulate. Even much earlier in life such animals have succumbed to the malady.

Moisture always has a potent influence in the epizootology of coccidiosis. The oocyst-infested poultry yard is never more dangerous to young chicks than during periods of copious precipitation. Freshly collected, succulent forage plants fed to young rabbits are looked upon as a particularly important predisposing factor. However, unless such foodstuffs are polluted by infective material their direct influence may be more apparent than real. It seems to be more likely that the greater flow of urine induced by such a diet and soaked into the litter of the cages may supply the moisture favorable to a rapid sporulation of the oocysts eliminated by the host animals present.

That coccidiosis may also occur in disastrous outbreaks in stables and feeding yards, even during the winter season, has been abundantly shown by many observers. Such outbreaks merely point to the abundance of infective oocysts present in the localities involved.

Bruce, as well as Roderick, who studied the disorder in some of the coldest parts of North America, report winter outbreaks as a characteristic feature of the epizootology of bovine coccidiosis. Cattle coming through the pasture season in relative safety begin to suffer from coccidiosis shortly after they occupy their winter quarters. No doubt, the animals were intensely infested with ripe oocysts. Moreover, the greater degree of concentration of carrier hosts in such a place must also be given consideration when the phenomenon is to be explained.

Wherever the greatest number of ripe oocysts are concentrated, whether in pasture, stables or feed yards, in summer or in winter, there also will exist the greatest coccidiosis hazard for susceptible host animals. Such conditions are most apt to be found in permanent pastures and in filthy enclosures more or less continuously occupied by coccidia-infested livestock, sick or healthy as the case may be.

An immunity to coccidiosis comparable to that engendered by certain bacterial infections probably does not exist. Andrews observed that one attack of coccidiosis (Isospora) seems to render cats and dogs non-susceptible to subsequent infestation by the same parasites and stated that this resistance lasts for 7 months and probably during life. On the other hand, several investigators deny the development of something akin to immunity after Eimeria infestations and claim that recovered animals remain subject to re-infection or to super-infection as long as they are young.

The apparent freedom of clinically manifest coccidiosis enjoyed by older animals may, at least in part, be accounted for by immunity to secondary infections of the intestine, which are always most formidable in the young.

The knowledge of immunity to intestinal protozoa is extremely meager, and even its existence remains as yet a matter of speculation. It is probably more correct to view the resistance to gross as well as to micro-parasites in the light of ecologic adjustments between parasites and hosts. For reasons entirely unknown, certain individuals of a species are, or become, unfit to serve as hosts. In others, parasite and host co-exist in an ideal relation. An equilibrium is established which makes it possible that a certain number of parasites are tolerated without causing damage to the host. If this equilibrium becomes upset or fails to be established, parasites may develop in excessive numbers with actual disease as a result.

In the parasitism by coccidia these conditions may be observed among a group of animals exposed to the same environmental conditions. Some individuals may succumb to an excessive parasitism. Others may remain entirely free of coccidia, whereas in a third group the coccidia remain present more or less constantly without causing any disturbance that can be clinically recognized. The animals belonging to the latter group constitute the healthy carriers.

Although coccidial disease is primarily the result of a specific parasitism, a distinction should be made between a mere parasitic invasion and the morbid state which may result from it. Disease in such a case may be regarded as being based upon a faulty host-parasite relation or adaptation. The problem is principally associated with the status of mutual adjustment, and as long as the governing factors remain unknown it can be approached only by speculation.

Prophylaxis.—The amelioration of the environment in which animals must exist is the principal task in the prevention of coccidiosis. Infested pastures should be avoided by animals which may become hosts to the coccidial species concerned. The permanent pasture has always supplied a special coccidiosis hazard when occupied year after year by the same susceptible animal species.

In the face of a more or less established coccidiosis risk, preference must be given to the rotation of pastures, or if permanent grazing grounds must be maintained as such it is advisable to have them occupied by a different species every year or at least to avoid them for a given type of livestock during alternate years.

Wet pastures should be drained; if surface-water accumulations

cannot be eliminated by drainage or filling, they should be rendered inaccessible to livestock by the erection of a fence.

The water supply, at pasture as well as in other enclosures, should be guarded against fecal contamination, and preference should always be given to a supply derived from deep wells. At the same time, accumulations of surface water, however small they may be, should be carefully eliminated. Self-cleaning watering devices are a valuable factor in the prevention of coccidiosis in poultry yards.

The rotation of the yards, permitting the ground to remain unoccupied by fowls for one year at least, would tend to make the environment much safer for young birds, especially if contact with older fowls can be similarly avoided.

If possible, young stock should be kept away from infected areas if a coccidiosis danger exists, and as in the case of fowls the prevention of contact with coccidia-infested adult animals will render this measure more effective.

The same principles should govern the protection of young stock kept in stables, poultry houses and yards. In such places, advantage should be taken of the fact that from 2 to 5 days are required before oocysts escaping with the feces become infective through sporulation. The scrupulous daily removal of all litter and fecal matter is a most potent measure in the prevention of coccidiosis.

If it is inconvenient or wasteful to destroy such material by burning, the manure should be deposited in a thick layer in a suitable place and covered with straw and earth. The heat developing as a result of the bacterial action in the moist material is ordinarily sufficient to destroy the parasites, the exclusion of the oxygen also constitutes a means tending to prevent sporulation.

Feed should be offered in a manner which precludes fecal contamination and should be so abundantly supplied that the animals are not forced to eat the bedding and stable wastes.

In view of the ever-present coccidiosis danger to young rabbits, their forage should always be placed well above the floor of the cage and the water should be supplied in containers so constructed that the entrance of the droppings can be definitely avoided.

Rabbit cages may be provided with a floor constructed of wire netting or hardware cloth of a mesh just wide enough to permit the fecal pellets to pass through. It is also practical to place beneath the wire floor a movable metal drawer in order to facilitate the removal of the collected droppings.

The feeding of sour milk to young poultry is reputed to be of value

in the prevention of coccidiosis. It is not certain that sour milk has a specific effect on the parasites, but it is a most excellent food, and the introduction of a certain amount of lactic acid in the intestinal tube may somewhat deter the development of certain micro-organisms which always have to be reckoned with as factors in secondary infection of the mucosa damaged by coccidial invasions.

The segregation of animals affected with coccidiosis can be approved because of the great number of oocysts which such animals are apt to contribute to their environment. However, in the presence of carrier animals in a good state of health, the value of this measure is only a relative one. It is doubtful if the elimination of healthy carriers, based upon the microscopic examination of the feces, can be recommended as a measure adaptable to the conditions imposed by the practical requirements of husbandry.

Owing to the marked resistance of the oocysts to chemical influences, the use of disinfectants is practically useless as a measure of protection.

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CHAPTER LI

BLACKHEAD

The name blackhead is commonly given to a transmissible disease particularly disastrous to young turkeys. The disorder, also described as infectious entero-hepatitis, essentially consists of a necrotic process primarily involving the ceca and later the liver.

In the younger turkeys, blackhead manifests itself by drowsiness, ruffled feathers, drooping wings and other signs of progressive weakness, usually accompanied by a more or less constant diarrhea. In the older birds the disease often shows a more chronic course and is less apt to cause the severe emaciation observed in the poults.

In a preponderating number of cases of spontaneous blackhead the ceca and the liver are the only organs involved. One or both of the blind guts may be affected, the lesions consisting of necrosis of the mucosa, thickening of the intestinal wall and a distension of the tube by a dry, caseous, friable mass which, on cross-section, often appears in concentric layers. In the liver, necrotic areas distinct or confluent are observed. In the older cases a plastic peritonitis is often a part of the patho-anatomic complex. Involvement of the lungs and kidneys has been encountered in spontaneous cases; in those experimentally induced, lesions were observed in other tissues and organs as well.

Blackhead was first described in this country and by 1892 had become a major problem of turkey growers in some of the New England states. Since the disease became well known in North America, it has also been observed in several European countries, in South Africa, in Australia and in parts of Asia. In fact, wherever turkey raising is practiced on a more or less extensive scale the disease is apt to be met with.

Blackhead is marked by a very high mortality rate, and it frequently constitutes the principal hazard associated with the production of turkeys. In many sections of the United States the disease has caused the growing of turkeys to be abandoned as unprofitable and has crowded this branch of poultry husbandry to the more recently settled and developed areas of the country.

Susceptible Species.—The turkey is the most susceptible of all the species which may serve as host for the etiologic factor of blackhead. Only in the turkey has the disorder assumed a distinct economic importance. However, blackhead is not infrequently observed in other avian species.

It is by no means unknown in the common fowl and may even bring about serious losses among brooder chicks. As will be pointed out later, evidence empirically acquired and experimentally sustained tends to show that chickens are commonly carriers of the blackhead virus, and that as a consequence, turkey raising and the maintenance of chickens on the same area has proved to be incompatible because of the blackhead hazard which accompanies the practice.

It is not at all improbable that, although blackhead is a turkey malady par excellence, the causative factor is an Old World micro-parasite existing in perfect adaptation to its chicken host, and *vice versa*, which, when acquired by the New World turkey found a mutually defective adjustment with disease as the ultimate result.

Aside from turkeys and common fowls, blackhead or its etiologic factor has been found in pea-fowls, pheasants, grouse and guinea-fowls, and the involvement of other bird species is by no means impossible.

The Virus of Blackhead.—The precise nature of the virus of blackhead is still a subject of debate, but there is considerable agreement among investigators that the etiologic micro-parasite is a protozoon. It was first described by Theobald Smith in 1895 and designated by him as *Ameba meleagridis.* This classification was contested by other authors who in turn regarded it as a species of coccidium, a *Trichomonas,* a *Histomonas* or even as a representative of *Haplosporidia.* Awaiting the final solution of the taxonomic problem presented by the blackhead parasite, Smith's original classification will be adhered to in this text.

Ameba meleagridis occurs in the blackhead lesions of the affected birds as well as in the contents of their ceca. Of its behavior when outside the body of a host, little or nothing is known.

Information about its resistance to external influences also is very meager. Tyzzer, Fabyan and Foot reported that the parasites occurring in the liver lesions of the turkey survive for at least 4 days at 5° C., deteriorate more rapidly at 22° C. and are immediately destroyed by freezing.

The latter observation may not be in accord with the common experience that the disease survives on farms situated in the coldest areas of the United States, where extremely low temperatures are apt

to prevail in the course of long winters. Without precise information regarding the possible existence of highly resistant forms of the parasite, or its survival in other host species, definite conclusions with reference to the parasite's longevity under the conditions mentioned may be profitably postponed.

Modes and Vehicles of Infection.—The micro-parasite which causes blackhead develops in the tissues of the intestine, gains the lumen by the ulcerative process it induces, and passes out of the body with the feces. The *Ameba meleagridis* contained in the body wastes and in the soil contaminated therewith remain viable for prolonged periods.

Although the feeding of blackhead lesions to normal turkeys frequently resulted in failure to transmit the disease, a substantial volume of experimental evidence indicates that the disorder can be induced by the feeding of virulent material from poult to poult, from the later to chicks, and *vice versa.*

It has also been possible to produce a characteristic and fatal blackhead by the subcutaneous inoculation of fresh liver lesions taken from an acute case of the disease. This tends to show that the micro-parasite is pathogenic *per se* and probably requires no complementary factors in order to cause disease. That the inauguration of the morbid process may be aided by defects of the cecal mucosa, however, cannot be doubted.

The fact that very young poults commonly succumb to typical blackhead was responsible for the popular notion that the eggs from which they were hatched may have been the primary source of the virus. This belief could not be sustained by experimental results. Eggs do not appear to carry the *Ameba,* and it has proved possible to raise healthy turkeys by the artificial incubation of eggs obtained from infected birds. It was further demonstrated that the turkey embryo apparently is not a suitable host for the blackhead parasite as healthy poults developed from eggs which were previously inoculated with the virus.

The discovery that the ova of the cecal nematode, *Heterakis papillosa,* may in some manner convey the blackhead parasites is of more than passing interest. The feeding of large numbers of embryonated ova to young turkeys not otherwise exposed has, in repeated experiments, resulted in bringing about the characteristic lesions of the malady under consideration. On the other hand, it could not be shown that the transmission and causation of blackhead were absolutely dependent on the presence of *Heterakis.*

Poults do not become as readily affected with the disease when

Heterakis eggs are but slowly ingested in relatively small numbers as when massive doses of ova are fed experimentally. Apparently, *Heterakis* may be a factor of etiologic significance, but how important it is and in what manner it plays a part has not as yet been definitely ascertained.

A conspicuous *Heterakis* infestation and a high incidence of blackhead may be correlated, but whether the worm eggs are entirely responsible for the phenomenon is an open question. The heavy worm invasion sustained by the birds may merely reflect a highly unsanitary state of environment, and, after all, this may be the chief factor of mischief.

All evidence, experimental, epizootologic, as well as empirical, tends to show that, in spontaneous blackhead, the virus is introduced into the body by means of contaminated food and water.

In the transmission of blackhead, the soil of areas occupied by turkeys and common fowls serves as a very potent reservoir of infection. It is a common observation that the tendency on the part of chickens to become the more or less permanent carriers of the blackhead ameba is responsible for the fact that turkey raising cannot well succeed in areas where the ordinary barnyard poultry is also maintained.

Once the parasites are introduced into the body they rapidly multiply in the intestinal mucosa, and either by means of the blood stream or by means of phagocytes they invade the liver. The lesions are produced by the mechanical action of mere numbers by which pressure is exerted on the cellular elements of the organs involved, with necrosis as an immediate result.

In young poults, especially, the invasion may proceed speedily; deaths from blackhead occurring 12 days after exposure are by no means uncommon. In older birds a longer period seems to be required for the development of fatal lesions.

Factors Favoring Infection.—All turkeys, young and old, are susceptible to blackhead, but not equally so. The younger the turkey, the greater its liability to the infection and the greater the tendency to develop rapidly fatal lesions. The highest mortality rate is shown by poults less than 3 months of age.

In the older birds the assault of the micro-parasites is, as a rule, better tolerated, and it is not an uncommon observation that adult turkeys in a state of apparently good health show extensive lesions of the disease. Within the adult age group, healed lesions are sometimes seen; in a certain number of the cases, recent and old lesions

may be simultaneously in evidence. Apparently no protective immunity is engendered by a previous lesion producing invasion.

Next to the influence of age, that of environment is the most potent in the propagation of the disease. Ground occupied year after year by turkeys and other poultry apparently become progressively more and more heavily contaminated by the specific micro-parasite until at last the surviving chances of poults become reduced practically to zero. The hazards associated with infected soil are further increased by defective drainage which makes it possible for the birds to partake of surface water.

Blackhead is purely a filth-borne disease, the incidence of which parallels the insalubrity of environment.

Prophylaxis.—Only a few years ago the opinion prevailed that owing to the incompleteness of the knowledge pertaining to the life history and biology of the etiologic factor it was not possible to approach an adequate prophylaxis with any degree of confidence. Furthermore, the almost instinctive passion to find a "cure" had not yet subsided to make way for the realization that preventive measures and not therapy offered the best prospect for the solution of the problem.

The earlier investigators must be credited with having laid the foundation upon which a rational prevention of blackhead might possibly be built. They showed that the disease was filth-borne, that the resistant barnyard fowls, as well as the adult turkeys, constitute formidable parasite carriers and spreaders, that the soil befouled by turkeys and other poultry serves as a possibly inexhaustible source of infection and that the egg plays no part in transmission.

Since the importance of environmental hygiene, has become more widely recognized, various methods of prophylaxis have been found to be more or less successful. In all of these the following principles served as guidance: first, the artificial incubation of turkey eggs and the use of clean brooders and clean runs for the poults; second, the avoiding of all contacts between poults and adult turkeys and other poultry; third, the selection of uncontaminated ground to be occupied by the poults or the practice of rotation of turkey yards in general; fourth, supplementing the measures mentioned by sanitary management and environmental hygiene, including that which pertains to food and water.

Because of the longevity of the micro-parasites in the soil, success may be partial only, as in time it may become difficult to find ground entirely free from infection. On the other hand, there is an abundance

of evidence that, under a sanitary régime as outlined, the incidence of blackhead can be substantially reduced.

By the elimination of the soil in the scheme of prophylaxis, it becomes possible to make the latter an absolute one. In accordance with the plan, the poults are incubated and brooded in the manner indicated. When sufficiently advanced in their development, the young turkeys are placed in enclosures and shelters provided with a floor constructed of stout wire netting or hardware cloth of 1-inch mesh. At first a ½-inch mesh is preferable. The netting is stretched on removable panels and placed well above the ground upon which all droppings are deposited. Water is provided in self-cleaning fountains, and the feeding troughs are placed outside of the fence of the enclosure and made accessible to the birds by means of suitable apertures. An area of 15 square feet per turkey is quite ample; probably this could be reduced to 10 square feet per bird.

Breeding stock should be placed in regular roomy yards during the mating and egg-laying period, and with these birds a blackhead hazard must, of course, be accepted.

The plan offers the additional advantage of being applicable to restricted areas of ground, and it can be carried through with convenience in feeding and watering, and a minimum requirement of cleaning.

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CHAPTER LII

HELMINTHOSES

THE part played by helminths as causes of livestock morbidity and as sources of reduced yields and productivity of domesticated animals is of sufficient moment to engage the interest of those concerned with animal husbandry and with preventive veterinary medicine.

The damage inflicted by parasitic worms varies greatly, ranging between a harmless infestation by a few helminths and the high rate of morbidity and mortality brought about by their massive invasion of large groups among an animal population.

Helminth species of importance from a livestock sanitary viewpoint are exceedingly numerous, and to devote space to every species in particular would transcend the scope of a work not exclusively pertaining to the subject of parasitology. In the paragraphs which follow, consideration can be given only to certain general principles, ways and means, which may be helpful in dealing with helminthoses of hygienic import.

The greater number of helminths are passively transmitted to the body of their hosts. Eggs or larvae are ingested with the food and drinking water contaminated with the body wastes of a previous host. Active invasion is less common, but must be reckoned with in the case of certain species (*Ankylostomum, Strongyloides,* etc.), the larvae of which are able to bore themselves in through the integument of their prospective hosts. A similar mode of infestation prevails also in the transmission of liver flukes, the miracidia of which penetrate the body of the snails which serve them as temporary hosts.

The pathogenicity of helminths arises from a number of factors, operating singly or in combination. Among them we recognize: purely mechanical influences, intoxications, predatory actions, and the inoculation and dissemination of pathogenic microbes.

Mechanical damage by helminths may take the form of obstruction of the intestinal canal by mere numbers, occlusion of the bronchi, the gall duct and other secretory or excretory passages, the traumata

inflicted by boring worms, compression of invaded tissues as well as the irritant effects arising from their presence, movements and modes of attachment.

Toxic action may be induced by the specific substances secreted or excreted by the helminths or set free by their final dissolution. Such intoxications may be relatively simple and direct in their *modus operandi* or of a more complex character (anaphylaxis). They are responsible for disturbances of nervous or circulatory origin, which find expression in convulsions, paralysis, anemia, etc.

Predatory action by parasitic worms may consist of abstraction of digested foodstuffs present in the alimentary tract, by the consumption or destruction of the cells and tissues of the host as well as by the ingestion of blood by certain intestinal helminths.

Parasitic worms penetrating various tissues and organs or migrating throughout the body in the course of their development may serve as vehicles for certain microbic pathogens of which they may be the passive carriers. Thus the larvae of *Ascaris* and other nematodes, migrating from the intestinal canal to more remote organs, are apt to transport bacteria capable of giving rise to morbid changes.

The degree of damage inflicted is, to a great extent, determined by the site of the helminths and especially by their numbers. The latter is probably the principal factor in the case of the parasitism of livestock which results in actual losses by sickness and death.

The ecologic relations which prevail under the conditions imposed by domestication and the practice of the more intensive types of animal husbandry are often conducive to massive helminthic invasions not often seen in the state of nature. Under such circumstances, the greater vulnerability of young animals commonly becomes responsible for excessively numerous worm populations in individual animals, and this is frequently the most conspicuous aspect connected with parasitization.

Numbers alone, however, do not in all cases account for the damage inflicted by helminths. Their degree of toxicity must also be reckoned with. Thus a single specimen of *Dibothriocephalus latus* may be capable of causing a profound anemia in its host.

In a more indirect manner, the presence of certain helminths has a bearing on the hygiene of animals, because of its relation to the use of pastures. In another chapter, pastures were mentioned as the most natural, the safest environment for domestic animals to exist in. To the young, the pasture is frequently a sanctuary in the face of certain microbic or deficiency diseases, but in connection with such pathogenic

helminths as strongyles, stomach worms, liver flukes and others, a given grazing ground may prove to be very opposite from a haven of refuge. The presence of such parasites may severely place limitations on pasture life as a universal factor in the promotion of animal well-being.

Factors Influencing Helminthic Infestation.—A number of factors are more or less essential in the etiology of the helminthoses. Among these the presence of moisture occupies a prominent place. Wet or swampy grazing grounds and moist stables and other enclosures are especially conducive to the parasitization of their occupants.

Moisture is imperative to the development of the embryos and the larvae of the pathogenic helminths and to the preservation of the eggs of many species. Some species are vulnerable to desiccation and succumb to its effect in varying lengths of time. Other species, on the contrary, show a marked tolerance toward drying. It was found, for instance, that hay collected from meadows infested with liver flukes, fed to cattle, sheep and rabbits after a storage of 8 months was still capable of causing a severe distomatosis in these subjects.

The freedom of parasitism in certain parts of the tropics was observed by Hall, who recognized among the causes to which he could attribute this phenomenon the extremely dry season of prolonged heat which followed the wet period during which torrential rains prevailed.

Such helminths as *Haemonchus* and the *Strongylus* also depend upon moisture to reach the point of vantage on the blades of grass from which the larvae would be most liable to be taken up by a prospective host. In the case of certain strongylids, Richters demonstrated that with the advent of sunshine and the disappearance of humidity the larvae returned to the soil or manure, and again began to ascend with the return of darkness.

Climates characterized by an even distribution of rainfall during the entire year tend to promote parasitism.

The vital functions and activities of the helminths, like those of other biologic forms, are governed by prevailing temperatures. Their life processes are not only stimulated by the body heat of their hosts but also by the higher temperatures prevailing in the extra-corporeal environment, in which many species must exist to complete the earlier phases of their life cycle.

The lower temperatures always either retard or suspend embryonation, even if the viability of certain species may be preserved in spite of severe freezing. Richters observed that the larvae of *Strongylus* remained viable for more than 2 years whilst exposed to all pos-

sible atmospheric conditions, ranging between temperatures of −13° F. to strong solar irradiation.

According to Ransom, the eggs of *Haemonchus contortus* will hatch at temperatures above 40 to 50° F. requiring from a few hours to 2 weeks to do so in accordance with the temperatures prevailing. Below 40° F. the eggs remain dormant, but retain their vitality for 2 or 3 months. Freezing and dryness kill the unhatched eggs; the larvae, on the contrary, show a marked degree of resistance to these influences. They are, however, inactive at temperatures below 40° F., and as long as these prevail they do not move up on the vegetation.

As a rule, parasitic invasion is more readily accomplished during the months of summer than during the colder seasons of the year, although, in the absence of moisture, prolonged great heat may prove to be lethal to many helminths.

The factor of age is markedly manifest in the etiology of many forms of helminthoses. In older animals, the parasites are commonly present in moderate numbers, but it is in the juvenile individuals that the most severe infestations are most frequently encountered. The cause or causes of this phenomenon are as yet unknown.

Apparently, the older animals have in some manner acquired a quality which inhibits the numerical development of helminths. From an ecologic viewpoint, the host-parasite relation prevailing in older individuals suggests a mutual adaptation by which host and parasite may both survive and thrive. Juvenile animals in heavily infested environments may become hyperparasitized before they can exercise the inhibitory influences apparently active in older individuals.

The state of health and nutrition of host animals exercises an influence on parasitism. Sick, stunted, weak or under-nourished animals are apt to entertain a more numerous helminthic population than strong, healthy, well-fed subjects of the same age group or species. However, there are cases in which this phenomenon may be more apparent than real, as it is by no means impossible that such hosts owe their impaired state of health or constitution entirely to the parasites, rather than that the number of parasites is influenced by the subnormal state of the host. On the whole, vigor of body and adequate food are assets for an actual or potential host.

In the case of the heteroxenous helminths, the presence of the permanent and intermediary hosts in the same environment is the *sine qua non* of their propagation. In the absence of sheep, dogs will not become infested with *Multiceps multiceps,* and vice versa; in areas

where all canines are kept free from this tapeworm, gid in sheep will remain a rare disorder.

For this group, the alimentary requirements of the host also exercise a determining influence in the etiology of certain helminthoses. An absolute herbivorous animal will, under natural conditions, not be apt to become infested with *Trichinella spiralis*.

The density of an animal population exercises an influence which promotes parasitism to a marked degree, especially if only one species preponderates. The occupancy of a given area of land or of a given enclosure by the same species of animal for a series of years is almost certain to bring about heavy helminth invasions, unless environmental conditions are extremely unfavorable to most species of parasitic worms. Permanent pastures, feed lots and paddocks as well as the overstocking of grazing ground are potent factors in the etiology of the helminthoses.

Therapy and Prevention.—From early times, man has bent his efforts to cope with the internal parasites of his livestock, whenever it has become apparent that their presence caused discomfort, disease or unthriftiness. These efforts, as a rule, consisted of the administration of vermifuges or vermicides, and on the whole the results of such treatment were more or less satisfactory to herd and flock owners. By this means, heavily infested animals could be visibly freed of large numbers of helminths and could be made to thrive better.

To a large extent, this practice prevails to this day; indeed, in several specific instances, it is imperative as the only means of reducing the economic damage which a helminthoses may be capable of inflicting. We must recognize the fact that medication often constitutes the only relief possible in situations which not uncommonly confront the livestock producer.

Therapeutic measures, though in some cases, successful in the reduction of the worm population of host animals to a bearable minimum, cannot solve the livestock sanitary problems associated with the helminthoses with any degree of finality. They are scarcely ever completely efficient; the parasites may occupy sites where anthelminthics do not reach them, or the worms may appear to be quite resistant to the agents used.

In dealing with certain helminths, drug treatment is as yet indispensable in spite of its imperfections, because it has likewise become established that their eradication by preventive measures alone also yielded but indifferent results. Prophylactic efforts are of practical

value in most instances where they can be based upon a more or less complete knowledge of the parasites concerned. However, as in therapy a final and complete disposal of the problem by prophylaxis is but rarely achieved.

Preventive measures may be quite effective, may even render medicinal treatment unnecessary, but the fact should be recognized that, in the solution of certain problems associated with the helminthoses, the use of vermifuges or vermicides cannot as yet be dispensed with. Therapy and prevention must often be made to complement each other.

The details of anthelminthic treatment, as well as those pertaining to the relative value of the agents used, may be omitted from a work more especially concerned with the prophylactic phases affecting animal health. Readers interested in the therapy of helminthoses will find valuable material in the many papers by Ransom, Hall and their collaborators as well as in the volume by Chopra and Chandler.

Prophylaxis.—The prophylaxis of the helminthoses in common with their control by drug treatment nearly always falls short when complete eradication is the objective of the efforts made. Various factors contribute an inhibitive influence on the general effectiveness of preventive measures. Among these, recognition must be given to the incompleteness of our knowledge of many of the parasites concerned in the etiology of the helminthoses.

In a large measure, effective prophylaxis must be based upon full information of the life history of helminths, in order to bring preventive action to bear especially on the point where the parasites may be most vulnerable to attack. For instance, a successful prophylaxis is quite attainable in the case of cestodes of which the life cycle is fully understood, such as *Taenia solium, T. saginata, Multiceps multiceps, Dibothriocephalus latus* and others. On the other hand, with the *Anaplocephalae* of the horse and the *Moniezíae* of the ruminants and *Thysanosoma actinoides* of which intermediary hosts are unknown, the problem is much more difficult to solve.

Of many internal parasites our knowledge is extremely scant or incomplete. Little, if anything, is known of their life cycle, their relations to environmental conditions, their resistance to adverse influences, their migrations and other important details which may be quite essential when prophylactic measures are to be devised.

Another factor which tends to render prophylaxis difficult is the ubiquity of many of the more important helminths. Among the domestic animals, it is uncommon, if not impossible, to find individuals

totally free of parasitic worms. In appraising this particular feature, cognizance should also be taken of the enormous fecundity with which most helminthic species are endowed.

A host animal which harbors a small number of helminths may not in the least suffer undesirable consequences from their presence. Yet, if consideration is given to the fact that these few parasites may yield millions of eggs to be distributed in an environment, the difficulties encountered in preventive attempts become more readily understood. In the state of natural existence when host animals roam far and wide, these stupendous masses of eggs merely tend to keep a parasitic species from extinction, only a small fraction of the eggs obtaining a chance to develop into mature worms. Under the conditions prevailing among the livestock on farms, the egg masses are scattered over more circumscribed areas and the chances of embryonated eggs or larvae finding a host are many times greater than where animals exist in the free state of nature.

The omnipresence of eggs and larvae in great numbers in situations where one or more helminthoses have become a problem constitutes a very potent obstacle to a satisfactory solution. Even when therapeutic efforts are combined with prophylactic measures, a final and complete eradication is but rarely achieved.

In addition to these inhibitions of a rational and successful prophylaxis, recognition must also be given to the economic limitations to which preventive measures must remain subject. On purely theoretic grounds, the complete eradication of helminths from an animal population and its environment can be accepted as within the range of possibility. Economic considerations must necessarily rule out many measures which are imperative to success.

After all, hygienic efforts, however useful they might be, cannot be permitted to become more costly than the evil against which they are directed. No doubt, a number of colts at pasture with their dams could be substantially protected against strongylosis by the prompt and adequate collection and disposal of the feces, as soon as possible after their evacuation, but the cost of such a procedure would be prohibitive for the majority of owners. Prophylactic measures either too costly or too irksome to the breeder of livestock are usually rejected, preference being given to the cheaper and more acceptable drug treatment, even if its value is only relative.

However, in spite of these obstacles to a universally successful prophylaxis of helminthoses, preventive measures have a definite place in any scheme designed to reduce the damage inflicted by them. In

essence, anthelminthic prophylaxis is based upon the double task of interrupting the life cycle of the parasites and of protecting the prospective host animals against infestation. This apparent simplicity of procedure is, to a great extent, changed to a marked complexity by the various conditions and circumstances under which they must be made to operate.

Viewing the problem from an epizootologic standpoint, Skriabine divides the helminthoses into two groups: the geohelminthoses and the biohelminthoses. The former are caused by worms which have a direct, simple life cycle and do not require the aid of intermediary hosts in their development (Monoxenous parasites). In their case the source of invasion is associated with dead matter: soil, water, food, body ejecta, in fact all environmental objects which may contain eggs or larvae. Living carriers serve in the transmission of the geohelminthoses only in a purely mechanical manner.

The parasites responsible for the biohelminthoses show a more complex life cycle, as they require intermediary hosts to complete it. They are heteroxenous. Biohelminths are taken in by the final hosts by the ingestion of part or all of the temporary ones. In their case, the epizootologic chain has two links. The two hosts have a direct contact with one another, when the parasite is transmitted from the intermediary to the final host. In this transmission a third link is interposed in the sequence of the life cycle, and, as in the geohelminths, dead matter (feces, water and food) performs its passive rôle.

Prophylaxis of the geohelminths involves the rupture of the chain at the point where the biologic link joins the inorganic one, as well as the prevention of all contact between the prospective host and environmental substances containing eggs or larvae.

In the prevention of the biohelminths the final hosts must be protected against contact with the intermediary ones, either by the elimination of the latter altogether, or by the destruction of the parts containing the immature parasites. In addition, the intermediary hosts must be protected against contact with the body wastes of permanent hosts and the eggs these may contain.

In all efforts in prophylaxis, the problem must be approached from various angles, in fact its solution must be attempted by all means promising results. No single measure, as a rule, will be effective. In accordance with the character of the helminths to be controlled, some particular measure may be emphasized, but in most cases all means available must be simultaneously resorted to within the limits of possibility.

Hosts and Prospective Hosts.—The specific existence of the obligate parasites which cause the various helminthoses is dependent on their ability to find new hosts and to enter into their bodies. In this transmission only the immature forms, eggs or larvae are to be reckoned with.

In the monoxenous parasites, this usually comes about through the medium in which eggs or larvae are contained, whereas in the heteroxenous helminths a sojourn in a temporary host is required, both as a suitable medium for their development and as a means for entering the final or permanent host.

In this transmission, a certain degree of propinquity between host and prospective host is always more or less essential. However, a close contact between such host animals is not strictly imperative in the case of the geohelminths, because the body ejecta, containing eggs and larvae, and the food or water contaminated by them, supply the vehicles carrying the parasitic forms. These forms commonly remain viable and active long after the original hosts have been removed.

In the case of the biohelminths, the same factors operate so far as transmission from the permanent to the temporary host is concerned. For the transfer from the latter to the former, a more intimate contact is required; this is made possible by the ingestion of the intermediary host itself or of such of its organs as contain the immature parasites.

The prevention of contact between prospective and active hosts or of environments contaminated by the latter has its place in a scheme of prophylaxis. This is always true when geohelminths and partially so when biohelminths are involved. In the absence of intermediary hosts a transmission would, of course, be impossible. However, in the face of a conspicuous biohelminthoses it must be assumed that the necessary intermediary host is also present, whether it is known or not.

As a measure of importance in prophylaxis, manifestly parasitized animals should not be introduced among such healthy stock as may serve as hosts. In certain cases, it is advisable to subject animals to be introduced to a clinical examination with this object in mind. For instance, when lungworms must be given consideration, animals showing symptoms indicating bronchial or other pulmonary disease should certainly be challenged with regard to the character of the underlying morbid condition. Sheep with diarrhea, in a poor state of nutrition, should never be introduced into a healthy flock unless it can be shown that those symptoms are not of helminthic origin.

Especial care must also be exercised in connection with the importation into a given country of animals which may be potential carriers of exotic helminths, capable of infesting the native stock. On farms where certain helminthoses constitute a definite hazard, special efforts should be made to bring about the separation of young animals from the infested adults. It is obvious that such a measure should also be applied to pastures and enclosures contaminated by the parasitized stock.

Owing to the fact that young animals are usually subject to a more severe infestation and are apt to show a greater vulnerability, their segregation should be practiced to the limit of its compatibility with sound husbandry, even if a complete protection may not always be achieved. By this means it is always possible to reduce the parasitic invasion to a minimum, and this, in itself, may constitute an effective protection against losses induced by morbidity as well as by mortality.

The consistent separation of juvenile and adult animals has proved to be useful in the helminthoses caused by species of *Ascaris, Heterakis, Strongylus, Haemonchus* and others, in accordance with its compatibility with livestock management. It can be most profitably applied to the helminthoses of poultry; in the case of mammals the fact that the young animals must consort with their dams tends to render achievement more difficult. For these, the segregation can but rarely be made complete, because the exigencies of husbandry must usually be compromised with.

In the management of the helminthoses caused by *Haemonchus contortus,* Ransom obtained favorable results by the following mode of procedure: During the autumn and winter the breeding ewes, the lambs born during the preceding spring, and the yearlings are kept separate. The ewes are permitted to graze without regard to the infestation present in the pastures. The lambs, on the other hand, are kept only in fields which had been plowed and planted with suitable forage crops since a previous occupancy by sheep. In such fields they are allowed to remain for several weeks or months and removed to other fields when the forage becomes exhausted.

This practice was continued throughout the following year, and the lambs were managed in a similar manner as yearlings during the autumn of the next year. After that they were handled as breeding ewes. This manner of management was supplemented by anthelminthic treatment of the lambs and yearlings, beginning about the middle of May and repeated monthly until September. In this period the

animals were removed to fresh grazing ground as forage crops developed.

A partial segregation can also be accomplished by the use of "creeps" or hurdles which permit the lambs to graze ahead of the ewes.

In the segregation of host and prospective hosts, consideration must also be given to hosts belonging to a species different from the ones to be protected. In this connection, Ransom called attention to the turkey as the probable natural host of *Syngamus trachealis,* a helminth particularly damaging to young chicks, and mentioned that evidence showed that the helminthosis "gapes" has a tendency to disappear from farms after the removal of turkeys.

In the control of certain biohelminthoses the separation of the actual and prospective hosts, and the biologic forms which may serve as intermediary hosts, is a most essential measure. Thus, in the face of distomatosis hazards, sheep and other permanent host animals should be kept away from snail-infested grazing grounds.

The edible intermediary hosts of such cestodes as *Taenia solium, T. saginata, Dibothriocephalus latus,* if infested by their cystic forms, should either be rejected as human food or consumed only after thorough cooking.

Dogs infested with *Multiceps multiceps* should not be permitted in environments where sheep raising is a part of animal husbandry. The dogs should either be freed of their parasites by anthelminthic treatment or be eliminated altogether. Especially stray dogs, coyotes and other members of the canine family should be destroyed. When coenuriosis occurs in the sheep, the heads of the carcasses should be adequately destroyed as a useful method in prophylaxis.

The control of mosquitoes and other flying insects which may serve as the intermediary hosts of filarids must also be given consideration as well as the part played by certain species of earthworms as the temporary hosts of the lungworm of swine. The elimination of rats from establishments where swine are maintained is obviously an essential measure in the prevention of trichinosis.

The prevention of the biohelminthosis caused by *Gigantorhynchus hirudinaceus* can be based upon the removal of swine from shady ground where the grubworms, which serve as temporary hosts of the helminths, are liable to abound. The destruction of the exoparasites (fleas) of dogs has a value as a prophylactic measure against *Dipylidium caninum.*

Environmental Amelioration.—Environmental factors play an im-

portant part in the etiology and epizootology of the helminthoses. These influences are principally determined by certain physical qualities of the soil, such as texture, impermeability and topographical conditions which tend to cause the accumulation of surface water, bogginess, etc. Infestation of the land by the previous occupancy of parasitized animals must also be recognized as an environmental factor.

Wet lands lend themselves especially to the successful completion of the life cycle of many helminths. Humidity is an essential to the embryonation or hatching of eggs, and to the development, preservation and movements of the larvae of certain geohelminths; in such heteroxenous parasites as liver flukes, the temporary hosts also depend upon a liberal supply of moisture for their existence and propagation.

There is epizootiologic evidence that the unknown, temporary hosts of the tapeworms of horses and ruminants also are more apt to be present on poorly drained land or in the low places frequented by the animals concerned. The amelioration of such areas by drainage is often the most effective means of prevention; in distomatosis it may, in certain districts, be regarded as quite imperative. Hupka observed that after the improvement of the grazing lands by drainage in districts which, within a few years, sustained a cattle loss of 50 to 80 per cent by distomatosis, the morbidity rate declined rapidly, and finally the disease disappeared altogether.

When land improvement by drainage or the filling of low places cannot be accomplished, the pastures should be temporarily (1 to 2 years) abandoned by the type of livestock endangered. Accumulations of surface water which cannot otherwise be eliminated should be rendered inaccessible to livestock by the erection of adequate fences.

The deep plowing of helminth-infested land materially tends to reduce the hazard of helminthoses and to hasten the final elimination of the parasites. Once turned under the soil, they apparently do not again reach the surface in numbers sufficient to cause conspicuous damage. According to Ransom, fields that have been well plowed, and on which a crop has been grown since a previous occupancy by ruminants, can be temporarily populated by sheep without involving them in risks caused by new invasions of *Haemonchus contortus.*

Food and Water.—With the exception of parasitic species transmitted by biting insects and of those the larvae of which may penetrate the skin, most helminths enter the body of their hosts by means of food and water. The prevention of their contamination constitutes

one of the most effective means of prophylactic import. Most readily accomplished when animals are kept in stables where attention is given to general cleanliness and to the prompt and adequate removal of fecal matter, prophylactic measures pertaining to the food are often difficult to carry out in pastures. There the eggs and larvae of the parasites concerned are often present in stupendous numbers, their viability may be an enduring one and the measures to be taken are apt to come in conflict with the profitable management of land and herds.

Under such conditions it is usually impossible to bring about a complete eradication of helminths, but it is commonly possible to suppress them to the extent of securing freedom from manifest disease. This may be achieved by various methods of procedure. One of these is the frequent rotation of grazing grounds and more particularly of those occupied by the more vulnerable young animals, for which the safest pasture should always be chosen.

The intermittent occupancy of pastures by a given host species reduces the number of eggs and larvae by the operation of various adverse conditions to which they may be exposed during the periods when their numbers are not being augmented by the evacuations of parasitized hosts. The longer the intermission between occupancies, the more effective will pasture rotation prove to be.

In the helminthoses caused by *Haemonchus contortus, Esophogastomum columbianum* and similar nematodes, pasture rotation has become a more or less indispensable means of control. Pasture rotation as a means in the prophylaxis of stomach-worm disease in sheep was carefully studied by Ransom, who, in the selection of his mode of procedure, took advantage of some of the phases of the life cycle of the causative species and of their reaction to conditions adverse to their viability.

He determined that land which was not occupied by ruminants for the period of one year will be quite safe for sheep, and that fields cultivated for a season and then planted in forage crops will likewise have become freed of viable eggs and larvae. It became also known that, during freezing weather, the eggs and the more vulnerable early stages of the larvae are destroyed, so that infested pastures may have become relatively safe during the colder season of the year.

In all schemes of pasture rotation in the control of stomach worms, the presence of infested adult sheep always constitutes a formidable obstacle to success.

Ransom states that the time required for a clean pasture to become infested after parasitized sheep were admitted depends upon the prevailing temperature, because in order for the land to become dangerous, the eggs deposited must have hatched, and the resulting larvae developed to a final stage, and these changes take place only when a suitable temperature prevails.

At temperatures remaining constant at approximately 95° F. the final invading stage is reached in 3 to 4 days. At 70° F. from 6 to 10 days are required, and at about 50° F. from 3 to 4 weeks are necessary to development to the stage when infestation can take place.

Ransom observed that, in the northern portions of the United States, parasitized and non-infested sheep may be placed in clean fields during the latter part of October and kept there until March or even later, with little or no danger of the clean sheep becoming infested. If, at the end of this period, they are removed to a clean grazing ground, they may remain there during the entire month of April with relative safety.

After that time the pastures become infested with progressively greater speed, and if the non-infested sheep are to be protected, it will be necessary to move them to clean pastures every 2 weeks during May, every 10 days during June and every week during July and August. After September first the period may again be increased. On most farms such a scheme of rotation would be quite irksome or possibly entirely impracticable, but its principle is sound. In many cases, however, the alternative of frequent medication would be preferred.

Aware of the fact that emphasis should be placed upon the protection of the lambs, Ransom suggests causing the latter to be born at a time of the year when there would be no danger of their becoming infested during the suckling and weaning period and then to separate them from the adults before the advent of warmer weather. When such a procedure can find application, only two clean pastures would be required, one for the ewes and lambs for fall and winter occupancy and another one for the lambs after weaning in March. Unfortunately certain hygienic and economic considerations may limit the employment of this method to only a relatively small number of establishments.

Dalrymple worked out a method of controlling nodular disease in sheep which is also applicable to the helminthoses caused by stomach worms and other nematodes. He selects a piece of land not previ-

ously occupied by sheep and upon it erects a protecting shelter. This shed should be divided into three compartments, the ewes occupying one end and the lambs the other, the middle one being reserved for the animals when they occupy the suckling pen.

The land is divided in two fields at right angles from the shed and the suckling pen in front of it. (See Fig. 78.) Between the two fields a ditch is made to drain the suckling pen and adjoining parts of the fields, separated by fences on each side of the ditch.

The suckling pen is kept free of vegetation and the manure is scrupuously removed at frequent intervals. At regular periods the ewes and the lambs are admitted to the suckling pen and again re-

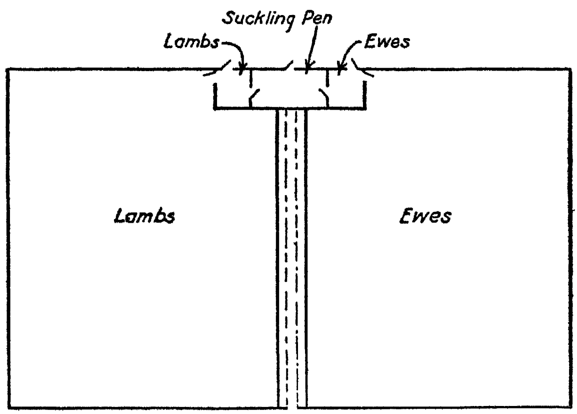

FIG. 78.—Pasture separation against "nodular disease." (After Dalrymple.)

moved to their respective fields, each class of animals always occupying the one reserved for it, at the completion of the feeding.

Thus, the only contact between the infested adults and the clean lambs takes place on neutral ground, where the lack of forage and the absence of fecal matter reduces transmission hazards to a minimum.

Permanent pastures must always be looked upon with suspicion on farms where a helminthoses has established itself. This is especially the case when they are continuously occupied by one host species. They may be utilized by other livestock or remain unoccupied by animals and then used as hay meadows. It should not be forgotten, however, that forage or hay grown on heavily infested land is not always safe on account of the viable eggs or larvae these substances may contain. Frequently it may be of advantage to subject

such lands to regular cultivation for a season or two, before using them as grazing grounds again.

The artificial pasture which is part of the scheme of crop rotation is perhaps the type with which the hazards of helminths is the least to be feared.

In addition to the risks associated with the forage grown on certain pastures, the plants themselves may show variations in parasitic contamination. The larvae of *Haemonchus contortus* and other nematodes tend to ascend on the leaves and sprigs of the pasture plants, and to do so especially when moisture and humidity are at their maximum. Thus it is always advisable, in the face of a helminthosis risk, to at least keep young animals away from the grazing grounds as long as the foliage is wet or damp with dew or precipitation water.

The abandonment of badly infested pastures must be considered when other clean land is available. Thus, in the case of distomatosis it may become necessary to keep animals altogether away from dangerous ground. Dry feeding in lots or other enclosures suitable for the purpose is often preferable to the exposure of animals to an almost certain infestation.

In the prophylaxis of the biohelminthoses the prevention of the contamination of foodstuffs consumed by intermediary hosts must form a part of the general scheme of action. When pastures or other enclosures inhabited by species which may serve as such hosts are also occupied by the prospective permanent hosts, the latter should be removed to a safer environment.

Longevity of the eggs of cestodes must be reckoned with, and if an infestation risk is actually feared the temporary cultivation or abandonment of dangerous grazing grounds is preferable to the practice of rotation.

Animal food derived from temporary hosts actually infested by the cystic forms of tapeworms should be rejected or destroyed. Thus, the heads of sheep infested with the *Coenurus cerebralis* must be carefully destroyed before the rest of the carcass can be devoured by members of the dog family, and the slaughter offal or carcasses of animals containing the cysts of other cestodes should not be used as food of animals which may serve in the capacity of permanent hosts.

In the prophylaxis of helminthoses caused by the poultry tapeworm, *Railletina cesticellus, R. tetragona* and *Choanotaenia infundibilum,* access to the common house flies which serve them as intermediary hosts should be prevented by whatever means of fly control may be applicable.

The destruction of the snails which play a part in the life cycle of the trematodes responsible for liver rot is to be attempted by the copper sulphate method of disinfestation wherever possible as a definite part of the prophylaxis of this biohelminthosis.

No attempt in the prophylaxis of the helminthoses can be entirely successful without adequate attention to the drinking water. Above all, accumulations of surface water should be avoided by prospective hosts. Pools, puddles and other bodies of stagnant water should either be eliminated or by means of fences be rendered inaccessible to animals liable to infestation. If such sources of supply as wells or springs are not available, the objectionable water should be passed through a simple sand filter and thus be rendered relatively safe.

Host and Environment.—The environment occupied by the host species is indispensable to many of the more harmful helminths. It is obvious that the denser the animal population on a given area, the greater will be the helminthosis hazard. The prevention of overstocking, although alone not sufficient as a measure of prophylaxis, will, nevertheless, tend to exercise a restraining influence on the degree of infestation.

Host-environment relations should also be taken in account, more particularly where permanent pastures must be utilized or where pasture rotation cannot be practiced with advantage. Pasture rotation may be supplemented by the rotation of hosts, based upon the fact that, in the case of parasites specific only for one host species, the infested environment can be safely occupied by other kinds of livestock.

Pastures dangerous to horses on account of the infestation of strongyles can be safely utilized by cattle, sheep and swine. Horses and swine can graze without risk on fields where the presence of stomach worms forced their abandonment by sheep.

On the other hand, the rotation of sheep, goats and cattle cannot be approved because, aside from *Haemonchus contortus,* other pathogenic nematodes are intertransmissible to the various species of ruminants.

Host rotation tends to render pasture rotation more effective and less costly. Abandoned pastures can be utilized by animals other than the ones endangered, and this economic advantage also permits the lengthening of the period of exclusion of the host species placed in jeopardy on the grazing ground involved. Pasture rotation combined with host rotation should be practiced as a measure of prophy-

lactic value wherever the character of a helminthoses warrants such a procedure.

The Manure.—One of the most difficult problems in the prophylaxis of animal diseases is associated with the dangers arising from the presence of an abundance of fecal matter in the environments in which animals must exist. This is particularly true in connection with the helminthoses in the transmission of which the fecalia play a major part. They are the vehicles by which parasite eggs leave the body of their hosts, and they constitute the principal means by which food and water become contaminated. Their adequate disposal, in a manner compatible with the requirements of husbandry, is as yet an unsolved problem in livestock sanitation.

At pasture it is still impossible to dispose of fecal matter in such a way that the contamination of the forage plants may be rendered difficult or impossible. The cost of collection would be prohibitive in nearly all cases, and even where it could be done, its ultimate effectiveness would remain more or less questionable.

The ejecta of parasitized animals are particularly potent as the vehicles of parasite eggs in swine and poultry, the feeding habits of which causes them to seek food in the soil or on its surface. In their case, the temporary abandonment of heavily polluted ground has thus far remained the only means of protection.

This measure has been quite successful in the control of *Ascaris lumbricoides* of swine in accordance with the plan proposed by Ransom. Swine are to be excluded from long-occupied hog yards, and particular stress is placed upon the necessity of keeping young pigs away from this type of environment. Care is taken to protect them from birth. They are farrowed in thoroughly cleansed pens, and all extraneous fecal matter and other filth is completely removed from the exterior of the sows prior to parturition. A week or 10 days after farrowing, the sows are moved to clean pastures, provided for in the scheme of crop rotation with this purpose in view. The results have thus far been so favorable that the method has thoroughly established itself in regions of the United States where swine growing is most extensively practiced.

In the management of the helminthoses of poultry the rotation of yards and the separation of the young stock from the adult birds and the ground contaminated by them has been shown to be of manifest prophylactic value.

Two methods may be used to prevent the manure collected in stables or other habitations from serving as a vehicle for helminths. It

may either be deposited on fields where there is no prospect of their becoming occupied by prospective hosts, or it may be treated to destroy the eggs or larvae which it may contain.

For the latter purpose the addition of a 10 per cent solution of sulphuric acid has been proposed, and the addition of quicklime has also been recommended. In view of the manifest resistance of parasite eggs to the action of chemicals it seems doubtful that the treatment with the substances mentioned will warrant the effort. If the eggs of helminths present in stable manure must be destroyed, it seems to be preferable to take advantage of the high temperature which develops in closely packed manure. Exposure to a temperature of 125° F. for several hours will destroy the viability of the eggs of most species of helminths. For this purpose, the manure may be packed in boxes or containers with double walls for the purpose of insulation. Or it may be piled in volumes of considerable size and covered by straw or earth to prevent the loss of heat. If the manure is very dry it is advisable to moisten the mass from time to time in order to promote the bacterial action within. To permit the manure to remain in storage until it has become thoroughly rotted would tend to render it safer with regard to the parasite eggs it may contain.

In the fertilizing of pasture lands by means of stable manure it is always advisable not to use that which is derived from the host species which is to occupy the pasture, or that from species which may also be infested with the helminths concerned.

Special attention is to be given to the ejecta of animals which have been subjected to anthelminthic treatment. Such animals should always be confined in enclosures where all fecal matter, as well as the helminths eliminated, can be carefully collected. All such material should be completely destroyed, preferably by burning.

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CHAPTER XLIII

SCABIES

A NUMBER of parasitic skin diseases known as scab, scabies or mange, because of their highly communicable character and capacity for damage must be given consideration from a livestock sanitary point of view. Other forms of mange characterized by a tendency to localize on certain parts of the body and not given to dissemination are of more interest to the clinician than to those more especially engaged in the prevention of animal diseases of public concern.

The diseases mentioned are caused by the presence and vital activities of certain parasitic mites. Scabies, or itch, is a disorder of great antiquity; apparently the causative parasites were observed in the remote past, particularly those connected with the disease affecting man. According to Gerlach, mites were mentioned by Avenzoar as early as the year 1174. The mange mites, parasitic on the domestic animals, attracted attention during a later period.

Those of the cat were first described in 1672 by Wedel; of the horse by Kersting in 1789; of sheep by Walz in 1809; of cattle and dogs by Gohier in 1812, and of swine in 1846 by Spinola.

The various forms of scabies are commonly designated by the generic name of the mites which causes them. Thus we speak of scabies as sarcoptic, psoroptic, chorioptic, demodectic, etc. The two former ones are of special livestock sanitary interest and as such must be given consideration in this text.

The parasitic mites by their presence and life habits cause cutaneous irritation resulting in a macular-papulous dermatitis and eczema, marked by intense pruritus, the formation of scabs and crusts, loss of hair and in certain well-known forms of the disease by a conspicuous thickening of the derma.

In the sarcoptic mange of equines the burrowing habit of the parasites is very prone to cause changes in the deeper layers of the skin; it is more difficult to eradicate than the psoroptic skin disease in other livestock in which the mites confine themselves to the cutaneous surface.

Sarcoptic horse mange usually declares itself first about the head and neck, from which areas a gradual extension to other parts of the body surface follows. The cases thus affected, if neglected for a considerable period, become involved in a marked thickening of the cutis and the formation of folds and corrugations (elephant skin). The cutaneous functions are disturbed, the general health impaired and in its worst aspects the resulting anemia and cachexia may affect the animal fatally.

In cattle, sarcoptic scabies is not an uncommon disease in this country, and apparently its incidence is increasing. It occurs among the cattle kept on farms, where it is known as "barn itch," as well as among range animals. Sarcoptic cattle scab must be regarded as a formidable cause of loss.

The sarcopts of cattle, as a rule, select as their habitat areas where the skin is thin and supple and where the hair coat is rather short and sparse. The disease frequently shows itself first about the inner face of the thighs, about the brisket and the root of the tail, from where it gradually spreads to other regions of the body. It gives rise to phenomena more or less common to all forms of scabies.

In time the disorder brings about loss of thrift, arrested growth and various functional disturbances often expressed by marked reduction in the yield of milk. The general impairment of health may eventually result in death.

Sarcoptic mange of swine is the most common of the skin diseases of these animals, and its prevalence is evidently increasing in this country. The initial phases of hog mange are usually observed about the head, the areas around the eyes and ears being particularly involved. From these localities, the other parts of the integument become gradually affected. This form of mange is accompanied by cutaneous irritation, severe itching, general unthriftiness and functional disturbances which ultimately may result in death, with or without the intervention of other diseases specific to swine.

Sarcoptic mange is also seen in sheep, where it remains confined to body parts not covered by the fleece.

Sarcopts are the most common cause of mange in dogs; in parts of the Near East, sarcoptic scabies is quite prevalent among camels.

Psoroptic scabies in its most formidable aspect is observed in sheep. One of the earliest known diseases of sheep, of world-wide distribution, it probably exceeds all other ovine disorders in its capacity for causing disaster to the flocks concerned. It affects the parts covered

by the wool and manifests itself by a marked cutaneous irritation and a denudation of the parts involved.

The loss of fleece is an important item in the damage inflicted by the disease; in addition, the loss of flesh and the marked unthriftiness induced by sheep scab must be reckoned with as well as with death losses by cachexia.

In cattle, psoroptic scabies is probably the form most frequently encountered in this country. Though more amenable to treatment than the sarcoptic bovine disease, its greater prevalence renders it, after all, the more damaging of the two disorders. For years, the disease constituted a conspicuous source of loss among the cattle of the western ranges of the United States.

This form of mange is apt to present itself first above the base of the tail, the neck and withers; its extension to other parts may be relatively slow, but the disease may eventually involve the entire surface of the body.

Affected animals show evidence of an intense pruritus, and the hair of the areas affected gradually disappears. The scabby cattle become unthrifty and lose weight; during cold weather they are apt to succumb in a poor state of nutrition and a greatly impaired power of resistance.

Psoroptic mange is also seen in horses. It affects the region of the mane, the root of the tail and other more or less protected places, and from these it may extend to other areas. As it occurs in equines this form of scabies but rarely becomes a subject for livestock sanitary control and has not gained the importance of the disease caused by sarcopts.

Psoroptic mange, known as ear mange, is common in rabbits; it is occasionally seen in goats as a rather benign skin disease of the ears also.

Chorioptic mange, habitually remaining localized in its sites of predilection and with but a slight tendency to be disseminated, has not become a subject of livestock sanitary concern although by no means without importance to the clinician.

Demodectic mange among farm livestock is apparently increasing its incidence, and although its spread may be slow, its progress should not altogether escape attention.

All forms of scabies are more or less cosmopolitan in their distribution.

Host Species.—The domesticated farm animals serving as hosts

to pathogenic sarcopts and psoropts are horses, cattle, sheep and swine.

The host-parasite relations observed in connection with the scabies peculiar to the species mentioned are highly specific in their nature. Each host species has its specific mite which can live and propagate itself on the body surface. Even though the parasites associated with the various host species may belong to one and the same species so far as this can be determined by their morphologic characters, they constitute definite varieties each adapted only to a certain specific host. Only upon this host can they sustain themselves, and they do not, in a permanent manner, invade representatives of other animal species.

However, heterologous mites may occur on animals other than those belonging to their optimum host species, may even remain there for a time or cause some initial lesions of the skin, but such an invasion is only temporary, and ultimately the parasites disappear through failure to reproduce themselves.

As will be pointed out in another place, scab mites are apt to remain alive for a certain period when removed from the skin of their hosts, in the litter and other parts of the environment. Thus, it is not surprising when they display capacity to do so also on the skin of other species, where warmth and humidity are more favorable to them than on environmental objects and substances.

Such aberrant varieties, as a rule, succumb on their foreign hosts about as quickly as they would in any other place removed from their natural habitat. Transmission of scabies from one host species to another is not to be feared, and in planning of prophylactic measures this factor need not be considered.

Only when the mites can leave their foreign hosts while still in a viable state and be transmitted to their own, is it possible that such parasites may become a factor in the maintenance of the disease to which they give rise. This danger is a remote one and is further reduced by the fact that in most cases the aberrant mites consist exclusively of males.

The Parasites of Scabies.—The mites etiologically related to the forms of scabies considered in this text are species of the genera *Acarus* (*Sarcoptes*) and *Psoroptes* of the family Sarcoptida, order Acarina, class Arachnida. Some of these species are scarcely visible to the naked eye, and others cannot well be seen without the aid of a magnifying glass.

The sarcopts are burrowing mites which feed on the soft cells of

the deeper strata of the epidermis, reached by means of tunnels made by the parasites. In these burrows, which run parallel to the surface of the cutis, the female mites deposit their eggs.

The mites of the genus *Psoroptes* do not burrow but occupy the cutaneous surface where they nourish themselves with lymph and blood procured by means of their piercing mouth parts which enable them to puncture the papillae and the superficial cell layers of the derma. The females of these species deposit their ova on the surface usually near the margins of the affected areas of the skin. Warmth and moisture are factors quite essential to the life and vital functions of the parasites.

The parasites of the more prevalent forms of scabies of the horse, cattle, sheep and swine are: *Acarus* (*Sarcoptes*) *scabei* var. *equi*, *Acarus* (*Sarcoptes*) *scabei* var. *bovis*, *Acarus* (*Sarcoptes*) *scabei* var. *suis*, *Psoroptes communis* var. *bovis* and *Psoroptes communis* var. *ovis*.

The life habits and characters of sarcopts and psoropts have become well known through the efforts of several investigators; even though their conclusions may not always be in full agreement, they closely represent the actual facts which govern mite existence in nature.

Nöller, observing the behavior of the horse sarcopt placed upon the skin of guinea-pigs, found that the mites required about 5 hours to burrow themselves in and that the subepidermal burrowing proceeded at a rate of 1 mm. per day. The females deposited from 2 to 3 eggs per day, more rarely 4 eggs. On the foreign host used in the experiment the ova hatched in about 68 hours.

His observations confirmed the earlier ones by Gerlach who found that mites kept on a watch glass lived for 5 to 6 days. Contained in scabs and kept at room temperature they died in about 8 days, but they lived for 1 to 3 days longer when the scabs were kept in a horse stable. On a moist piece of skin, mites could still be observed to be alive after 3 weeks, but they did not survive much longer.

Sarcopts, deprived of food, lived longest in a moist air and at a rather cool temperature. Apparently humidity is more favorable to longevity than warmth, as at higher temperatures in a dry air they succumbed rapidly.

Larvae kept in a humid incubator died in 5 to 6 days; the adults contained in scabs at the temperature of 22° C. prevailing in a horse stable, or kept in moist as well as in dry manure, were lifeless after a sojourn of 10 days.

Infested scabs kept in a very damp refrigerator at 7.5° C. for 10 to 13 days yielded living mites which, when warmed, survived for 15 days longer. An exposure prolonged to 19 days or more destroyed them.

When kept in the manure of a horse stable during the heat of summer, the mites had lost vitality after a period of 10 days. Scabs kept in an ice-chest and then incubated for 3 days yielded no living mites and no larvae were hatched out during that time. The mites became perfectly motionless in the refrigerator, but at temperatures of 25° to 40° C. they were lively and moved at a speed of 1 mm. per second.

Nöller's observations showed that the capacity of the ova for hatching disappears in a shorter time than the maximum surviving period of adults in an environmental situation.

Cameron, who studied *Acarus* (*Sarcoptes*) *scabei* var. *bovis* observed that in an incubator at 37° C. the mites did not survive longer than 3 days, whereas those kept damp in a refrigerator managed to live as long as 11 days. His mites lived up to 7 days when kept at room temperature, but if exposed to sunlight none survived the second day and most of them were dead in a few hours. Eggs kept in an ice chest for a week or more failed to hatch even when they were subsequently placed in an incubator. At room temperature 10 of 38 eggs hatched after 3 to 8 days; of 18 eggs kept at room temperature, but in the dark, only 4 were hatched out.

According to Shilston, the females of *Psoroptes communis* var. *ovis* deposited 20 to 24 eggs shortly after one another. These hatched in 4 to 7 days, and the larvae became adult after 3 to 4 moultings, being capable of reproduction in 14 to 17 days. He estimated that at this rate 1 female psoropt may have a progeny of 1,500,000 mites within a space of 3 months. The female mites die in 3 to 5 weeks after ovipositing.

The eggs remained fertile for 2 to 4 weeks in the presence of moisture, but only for 4 to 6 days if kept in a dry place. Mites, as well as eggs, are killed in 1 hour when exposed to temperatures of 50 to 70° C.

Shilston states that the mites are known to be unable to live for more than 4 weeks apart from sheep, and that eggs cease to be fertile after 10 days. In his own experiments all mites were dead in 21 days.

Bedford observed that the eggs of the psoropts of sheep hatched in 2 days when placed in contact with the skin, and in 3 days when

they were 0.5 to 1 mm. removed from it. Ova tied in long wool $1\frac{1}{2}$ inches removed from the skin were observed to hatch in 6 to 8 days.

The newly hatched larvae attacked the skin very quickly and soon commenced to grow. After feeding for about 36 hours, they became quiescent. Usually they changed to nymphs in 2 days and always within 3 days. The nymphal stage endured for 3 to 4 days and the mites became quiescent before moulting into adults, the males always appearing a few hours before the females. After the moulting the adults fed for a brief period and then copulated. After remaining in copula for 24 to 28 hours the females were found to contain ova and soon began to oviposit.

Bedford placed a large number of adult psoropts in manure, wool or scrapings and found that they did not survive for more than 10 to 11 days. He also determined that the larvae and nymphs do not live as long as the adults, most of them dying from the second to the fourth day after being removed from the host. The longest survival period for a larva was 3 days and for nymph 8 days.

Eggs kept in an incubator at 37° C. hatched in 2 days if the atmosphere was moist, but failed to do so in a dry one. When kept in a refrigerator for 10 days and then transferred to an incubator they usually hatched on the third day. If they were kept in the ice-chest for longer periods they failed to hatch. When kept at room temperature all eggs hatched in 5 days in summer, but hatching did not take place during the winter months.

All ova placed in dry sheep manure at room temperature failed to hatch during summer as well as during winter. Ova exposed to sunlight shriveled up within a few hours.

Erhardt, who also studied the mites of sheep scab, found that their optimum living conditions when they were removed from their hosts are moist air and a temperature of 12.5 to 19° C. So exposed they may live for 3 to 4 weeks.

Temperatures above or below the ones mentioned reduced the periods of survival. The mites live for 1 to 3 weeks in moist air at temperatures of 0 to 12.5° C.; up to 3 days at —6.5 to 0° C., and only for a few hours at temperatures lower than —6.5° C.

In humid air of a temperature of 19 to 38° C. the mites survived as long as 12 days. In the presence of dry heat they succumbed much sooner, and in an absolutely dry atmosphere at 38° C. they were dead within a day. At still higher temperatures they may be destroyed in less than 1 hour. They may live as long as 12 days in

cold water and as long as 14 days in water at room temperature, but water heated to 85° C. kills them at once.

The hides of scabby animals are freed of living mites when dried for at least 3 weeks, but if kept moist this period may be prolonged to 4 to 6 weeks. Skins frozen through for 1 week, in the course of a severe winter, no longer contained living mites.

The process of tanning destroys the mites with certainty, and placing the hides in a 10 per cent suspension of calcium hydrate brings about the same result. Heating the hides to 70° C. causes complete disinfestation within a short time.

Modes and Vehicles of Infestation.—All forms of scabies are highly communicable, and in the majority of cases the transmission comes about by direct contact between scabby or mite-bearing animals and normal ones. Although such a contact will generally result in the transmission of the disease there is reason to believe that in a considerable number of cases the contact must not only be intimate, but also rather prolonged.

The promptness and certainty of transmission is also modified by the number of mites present on the affected animals. Thus the transmission of mites by a recent case of sheep scab is much more uncertain and slower in its operation than in the case of chronic scabies of the horse, in which the abundant incrustations of the skin are apt to contain parasites in much larger numbers.

It has been experimentally shown that a healthy sheep kept in the closest contact with two scabby ones for 2 hours escaped infestation. In two other experiments of a similar nature a healthy sheep was kept in contact with two scabby ones; in one of these, 7 days elapsed before transmission could be demonstrated by microscopic examination, and in the other trial 10 days passed before the healthy animal could be shown to be infested. A transitory contact, thus, is not always accompanied by a positive transmission hazard, although it would be imprudent to disregard the danger, no matter how brief the contact may have been.

It is not always possible readily to recognize the primary source of infection among a number of animals in which scabies has declared itself. The possibility that mites may exist on certain host animals on which, for reasons as yet unknown, they fail to multiply normally, must be reckoned with. With the advent of more favorable living conditions, the mites may recuperate, gain in vitality, begin to reproduce, and eventually be transmitted to cause disease.

In a few instances psoropts have been discovered in the ears of

sheep when other parts of the body have not been invaded. Such mites may serve as a source of infestation, and the phenomenon may explain the unexpected appearance of scabies in flocks apparently not exposed to outside contacts.

In the psoroptic mange of cattle, all manifestations of the disease may completely disappear during the summer season, and yet living mites be constantly present. With the advent of colder weather and the acquisition of a heavier hair coat, scabies is apt to declare itself in such animals. Introduced at any time among healthy cattle, they are able to transmit their mites and become responsible for an outbreak of scabies. Horses, likewise, may be carriers of sarcopts without presenting clinical evidence of the infestation.

Although direct contact with affected animals is always the most prolific source of scabies, indirect exposure by means of environmental objects or living vehicles must also be taken into account. In this mode of transmission, grooming utensils, blankets and bedding may play a part.

Infested premises must, for a certain period, be regarded as a means of indirect contact. As a rule, mites do not live for more than 4 weeks in such situations, but they may have an active part in transmission for longer periods and hence such localities must be regarded with caution. On the whole, however, this source of danger is commonly over-estimated.

It is entirely conceivable that birds and flying insects may be able to serve as vehicles for scab-mites, but there certainly is no evidence to indicate that such a mode of transmission is more than a very exceptional one.

In all forms of scabies, the incubation periods vary greatly in length in accordance with the number and species of the mites involved. Infestation by a small number of egg-bearing psoropts or by a few females and males may not become apparent for 4 to 6 weeks. In the case of sarcopts, commonly present in greater numbers, scabies may declare itself after an incubation of only 1 week.

Factors Favoring Infestation.—Certain factors tend to render infestation by scab mites more or less damaging, on the whole, whereas few influences change the epizootology of scabies once the animals become thoroughly exposed to the disease.

The progress of invasion may be advanced or retarded, the death-rate may be increased or decreased in the presence of certain factors or conditions, but regardless of these, the status of the herd or flock involved will, in time, be about the same.

In some forms of mange, season may prove to have an influence on the nature of the cases, but not always on the dissemination of the parasites. Psoroptic cattle scabies is apt to disappear in summer to reassert itself again in winter, and even the mange of horses caused by sarcopts spreads more slowly during warm weather than in winter when the animals are more closely confined. It is not improbable that the relative thickness of the hair coat is as potent an influence in causing these phenomena as season *per se.*

In sheep, scab transmission, on the whole, takes place more readily in individuals recently shorn than in those covered by a heavy fleece, but once the parasites have established themselves, the heavily fleeced ones commonly become more severely and more rapidly invaded. The finer- and denser-wooled sheep are apt to suffer more from scabies than the coarser breeds.

The sarcopts of swine are prone to invade the younger animals more readily than the older ones, although the latter do not fail to contract mange when adequately exposed. As a rule, the younger swine, more sensitive to the debilitating influences of under-nourishment, concurrent infections and hygienically faulty environments, suffer the most after infestation. This is also true of other species, and it must be accepted as a general rule that animals in a poor state of nutrition, of weak or inferior constitution, not only become more readily infested, but also show scabies in a more generalized and more damaging form.

Exposure to cold, damp and otherwise inclement weather apparently aggravates the disease, and combined with the influences of a filthy place of shelter and of malnutrition may increase mortality in a marked degree.

Proper and adequate feeding manifestly tends to favor animals affected with scabies; under certain circumstances it may materially reduce the damage caused by the disorder in all types of livestock, but especially in sheep.

The dissemination of scabies frequently follows the channels of the livestock trade, and animals in transit may become particularly exposed to mite infestation.

Prophylaxis.—In the prophylaxis of scabies the prompt and effective disinfestation (see Chapter XIII) by dipping and other methods of treatment of the animals affected or exposed is the principal factor. The mite-carrying animals are by far the most prolific source of new infestations, and without the thorough elimination of the mites all other measures would be futile.

The enclosures in which scabby animals have been kept and environmental objects used in their care and grooming should also be cleaned and disinfested. Although experimental evidence indicates that mites in such places and on such objects do not survive for more than 4 weeks, prudence demands that they be left unoccupied and unused for longer periods. Recently dipped or treated animals are less endangered by environmental infestation than others, but even in their case no risks should be taken.

When, after the discovery of scabies in a group of animals, dipping operations cannot immediately be undertaken, the manifestly scabby individuals as prolific purveyors of mites should be kept segregated from the others during the interim.

Scabies, as a highly communicable disease, should be subject to quarantine measures in a manner similar to those in force against other transmissible disorders. Affected or exposed animals should be held on their range or farms, and contact with all livestock of the same species should be rigidly prevented until they are successfully disinfested. Shipment for immediate slaughter can be permitted if facilities to prevent contact with healthy stock can be provided.

Animals en route to disease-free areas or farms should be challenged while in transit, and if found to be scabby they should be subjected to dipping at the nearest point available for the purpose. If railway cars or vessels are used in transportation, these should be subjected to disinfestation also.

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